# INTERNATIONAL STANDARD

# ISO 1438

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# Hydrometry — Open channel flow measurement using thin-plate weirs

*Hydrométrie — Mesure de débit dans les canaux découverts au moyen de déversoirs à paroi mince*

Reference number
ISO 1438:2008(E)

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# Foreword

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International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 1438 was prepared by Technical Committee ISO/TC 113, *Hydrometry*, Subcommittee SC 2, *Flow measurement structures*.

This second edition cancels and replaces the first edition (ISO 1438-1:1980), of which it constitutes a technical revision. It also incorporates the Amendment ISO 1438-1:1980/Amd 1:1988.

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# Hydrometry — Open channel flow measurement using thin-plate weirs

## 1 Scope

This International Standard defines the requirements for the use of rectangular and triangular (V-notch) thin-plate weirs for the measurement of flow of clear water in open channels under free flow conditions. It includes the requirements for the use of full-width rectangular thin-plate weirs in submerged (drowned) flow conditions.

## 2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 772, *Hydrometry — Vocabulary and symbols*

## 3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 772 apply.

## 4 Symbols and abbreviated terms

| | | |
|---|---|---|
| $A$ | $m^2$ | area of approach channel |
| $B$ | m | width of approach channel |
| $b$ | m | measured width of the notch |
| $b_{max}$ | m | width of notch at maximum head (V-notch) |
| $C$ | | discharge coefficient (gauged head) |
| $C_d$ | | coefficient of discharge |
| $f$ | | drowned flow reduction factor |
| $fC$ | | combined coefficient of discharge |
| $C_v$ | | coefficient of velocity |
| $e_b$ | m | random uncertainty in the width measurement |
| $g$ | $m/s^2$ | acceleration due to gravity |
| $H$ | m | total head above crest level |
| $h$ | m | upstream gauged head above crest level (upstream head is inferred if no subscript is used) |
| $J$ | | numerical constant |
| $l$ | m | distance of the head measurement section upstream of the weir |
| $n$ | | number of measurements in a set |
| $p$ | m | height of the crest relative to the floor |
| $Q$ | $m^3/s$ | volumetric rate of flow |
| $S$ | | submergence ratio, $h_2/h_1$ |

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| | | |
|---|---|---|
| $S_1$ | | modular limit |
| $\overline{V}$ | m/s | mean velocity |
| $U$ | % | expanded percentage uncertainty |
| $u^*(b)$ | % | percentage uncertainty in $b$ |
| $u^*(C)$ | % | percentage uncertainty in $C$ |
| $u^*(E)$ | % | percentage uncertainty in datum measurement |
| $u^*(h_1)$ | % | percentage uncertainty in $h_1$ |
| $u^*(Q)$ | % | percentage uncertainty in $Q$ |
| $\alpha$ | ° | notch angle |

**Subscripts:**

1 upstream
2 downstream
e effective
r rectangular
t triangular

# 5 Principle

The discharge over thin-plate weirs is a function of the upstream head on the weir (for free-flow), upstream and downstream head (for drowned flow), the size and shape of the discharge area and an experimentally determined coefficient which takes into account the head, the geometrical properties of the weir and approach channel and the dynamic properties of the water.

# 6 Installation

## 6.1 General

General requirements of weir installations are described in the following clauses. Special requirements of different types of weirs are described in clauses which deal with specific weirs (see Clauses 9 and 10).

## 6.2 Selection of site

The type of weir to be used for discharge measurement is determined in part by the nature of the proposed measuring site. Under some conditions of design and use, weirs shall be located in rectangular flumes or in weir boxes which simulate flow conditions in rectangular flumes. Under other conditions, weirs may be located in natural channels as well as flumes or weir boxes, with no significant difference in measurement accuracy. Specific site-related requirements of the installation are described in 6.3.

## 6.3 Installation conditions

### 6.3.1 General

Weir discharge is critically influenced by the physical characteristics of the weir and the weir channel. Thin-plate weirs are especially dependent on installation features which control the velocity distribution in the approach channel and on the construction and maintenance of the weir crest in meticulous conformance with standard specifications.


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### 6.3.2 Weir

Thin-plate weirs shall be vertical and perpendicular to the walls of the channel. The intersection of the weir plate with the walls and floor of the channel shall be watertight and firm, and the weir shall be capable of withstanding the maximum flow without distortion or damage.

Stated practical limits associated with different discharge formulae such as minimum width, minimum weir height, minimum head, and maximum values of $h/p$ and $b/B$ (where $h$ is the measured head, $p$ is the height of crest relative to floor, $b$ is the measured width of the notch and $B$ is the width of the approach channel), are factors which influence both the selection of weir type and the installation.

### 6.3.3 Approach channel

For the purposes of this International Standard, the approach channel is the portion of the weir channel which extends upstream from the weir a distance not less than 5 times the width of the nappe at maximum head. If the weir is located in a weir tank, ideally the length of the tank should equal to 10 times the width of the nappe at maximum head. Information on the use of small weir tanks is given in Annex A.

The flow in the approach channel shall be uniform and steady, with the velocity distribution approximating that in a channel of sufficient length to develop satisfactory flow in smooth, straight channels. Figure 1 shows measured velocity distributions perpendicular to the direction of flow in rectangular channels, upstream from the influence of a weir. Baffles and flow straighteners can be used to simulate satisfactory velocity distribution, but their location with respect to the weir shall be not less than the minimum length prescribed for the approach channel.

The influence of approach-channel velocity distribution on weir flow increases as $h/p$ and $b/B$ increase in magnitude. If a weir installation unavoidably results in a velocity distribution that is appreciably non-uniform, the possibility of error in calculated discharge should be checked by means of an alternative discharge-measuring method for a representative range of discharges.

If the approach conditions are judged to be unsatisfactory, then flow straighteners shall be introduced in accordance with Annex B.


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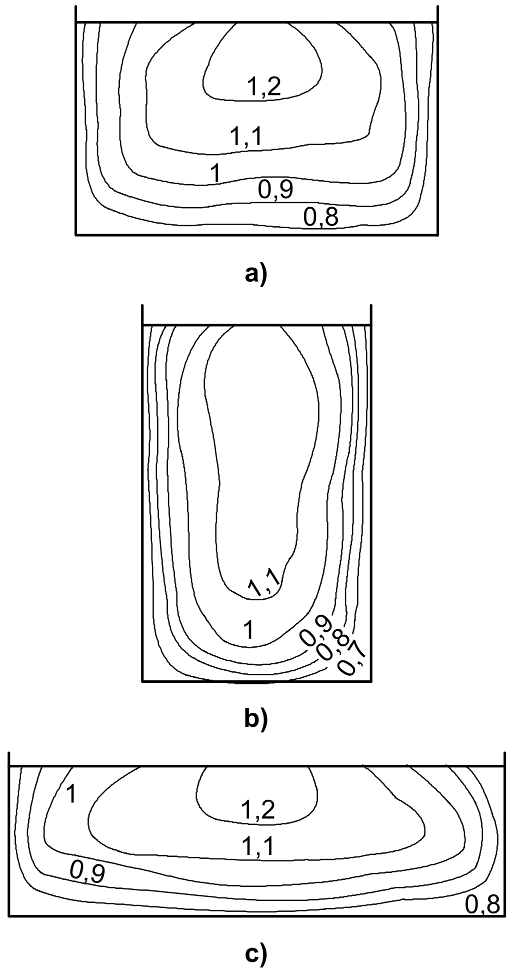


NOTE The contours refer to values of local flow velocity relative to the mean cross-sectional velocity.

**Figure 1 — Examples of normal velocity distribution in rectangular channels**

### 6.3.4 Downstream channel

For most applications, the level of the water in the downstream channel shall be a sufficient vertical distance below the crest to ensure free, fully ventilated discharges. Free (non-submerged) discharge occurs when the discharge is independent of the downstream water level. Fully ventilated discharge is ensured when the air pressure on the lower surface of the nappe is fully ventilated. Drowned flow operation is permitted for full width weirs under certain conditions (see 9.7.2). Under these circumstances, downstream water levels may rise above crest level.

## 7 Measurement of head

### 7.1 Head measuring devices

In order to obtain the discharge measurement accuracies specified for the standard weirs, the head on the weir shall be measured with a laboratory-grade hook gauge, point gauge, manometer, or other gauge of equivalent accuracy. For a continuous record of head variants, precise float gauges and servo-operated point gauges can be used. Staff and tape gauges can be used when less accurate measurements are acceptable.

Additional specifications for head-measuring devices are given in ISO 4373 [1].


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## 7.2 Stilling or float well

For the exceptional case where surface velocities and disturbances in the approach channel are negligible, the headwater level can be measured directly (for example, by means of a point gauge mounted over the water surface). Generally, however, to avoid water-level variations caused by waves, turbulence or vibration, the headwater level should be measured in a separate stilling well.

Separate stilling wells are connected to the approach channel by means of a suitable conduit, equipped if necessary with a throttle valve to damp oscillations. At the channel end of the conduit, the connection is made to floor or wall piezometers or a static tube at the head-measurement section.

Additional specifications for stilling wells are given in ISO 1100-1 [2].

## 7.3 Head-measurement section

### 7.3.1 Upstream head-measurement

The head-measurement section shall be located a sufficient distance upstream from the weir to avoid the region of surface drawdown caused by the formation of the nappe. On the other hand, it shall be sufficiently close to the weir that the energy loss between the head-measurement section and the weir is negligible. For the weirs included in this International Standard, the location of the head-measurement section will be satisfactory if it is at a distance equal to 2 to 4 times the maximum head ($2h_{max}$ to $4h_{max}$) upstream from the weir.

If high velocities occur in the approach channel or if water-surface disturbances or irregularities occur at the head-measurement section because of high values of $h/p$ or $b/B$, it may be necessary to install several pressure intakes to ensure that the head measured in the gauge well is representative of the average head across the measurement section.

In the case of a full-width thin-plate weir, the effect of frictional effects upon the upstream channel requires an adjustment to the standard coefficient of discharge. The correction is in terms of both $l/h$ and $h/p$ and given in Table 1.

**Table 1 — Factors to be applied to the standard discharge coefficient values**

| $h/p$ | $l/h$ | | | |
|---|---|---|---|---|
| | 2 | 4 | 6 | 8 |
| **3,5 to 4,0** | 1,00 | 1,00 | 0,96 | 0,92 |
| **3,0 to 3,5** | 1,00 | 1,00 | 0,97 | 0,94 |
| **2,5 to 3,0** | 1,00 | 1,00 | 0,98 | 0,96 |
| **2,0 to 2,5** | 1,00 | 1,00 | 0,99 | 0,98 |
| **Less than 2,0** | 1,00 | 1,00 | 1,00 | 1,00 |

### 7.3.2 Downstream head measurement

If the weir is to be operated in the submerged (drowned) flow range, a measurement of downstream head is required in addition to that upstream. The downstream head measurement position shall be $10\ h_{max}$ downstream from the upstream face of the weir. If a stilling well is included in the design, it is recommended that the downstream head measurement be located no closer to the weir than $4\ h_{max}$.

## 7.4 Head-gauge datum (gauge zero)

Accuracy of head measurements is critically dependent upon the determination of the head-gauge datum or gauge zero, which is defined as the gauge reading corresponding to the level of the weir crest (rectangular

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weirs) or the level of the vertex of the notch (triangular-notch weirs). When necessary, the gauge zero shall be checked. Numerous acceptable methods of determining the gauge zero are in use. Typical methods are described in subsequent clauses dealing specifically with rectangular and triangular weirs. (See Clauses 9 and 10.)

Because of surface tension, the gauge zero cannot be determined with sufficient accuracy by reading the head gauge with the water in the approach channel drawn down to the apparent crest (or notch) level.

## 8 Maintenance

Maintenance of the weir and the weir channel is necessary to ensure accurate measurements.

The approach channel shall be kept free of silt, vegetation and obstructions which might have deleterious effects on the flow conditions specified for the standard installation. The downstream channel shall be kept free of obstructions which might cause submergence or inhibit full ventilation of the nappe under all conditions of flow.

The weir plate shall be kept clean and firmly secured. In the process of cleaning, care shall be taken to avoid damage to the crest or notch, particularly the upstream edges and surfaces. Construction specifications for these most sensitive features should be reviewed before maintenance is undertaken.

Head-measurement piezometers, connecting conduits and the stilling well shall be cleaned and checked for leakage. The hook or point gauge, manometer, float or other instrument used to measure the head shall be checked periodically to ensure accuracy.

If a flow straightener is used in the approach channel, perforated plates shall be kept clean so that the percentage open area remains greater than 40 %.

## 9 Rectangular thin-plate weir

### 9.1 Types

The rectangular thin-plate weir is a general classification in which the rectangular-notch weir is the basic form and the full-width weir is a limiting case. A diagrammatic illustration of the basic weir form is shown in Figure 2 with intermediate values of $b/B$ and $h/p$. When $b/B = 1{,}0$, that is when the width of the weir ($b$) is equal to the width of the channel at the weir section ($B$), the weir is of full-width type (also referred to as a “suppressed” weir, because its nappe lacks side contractions).


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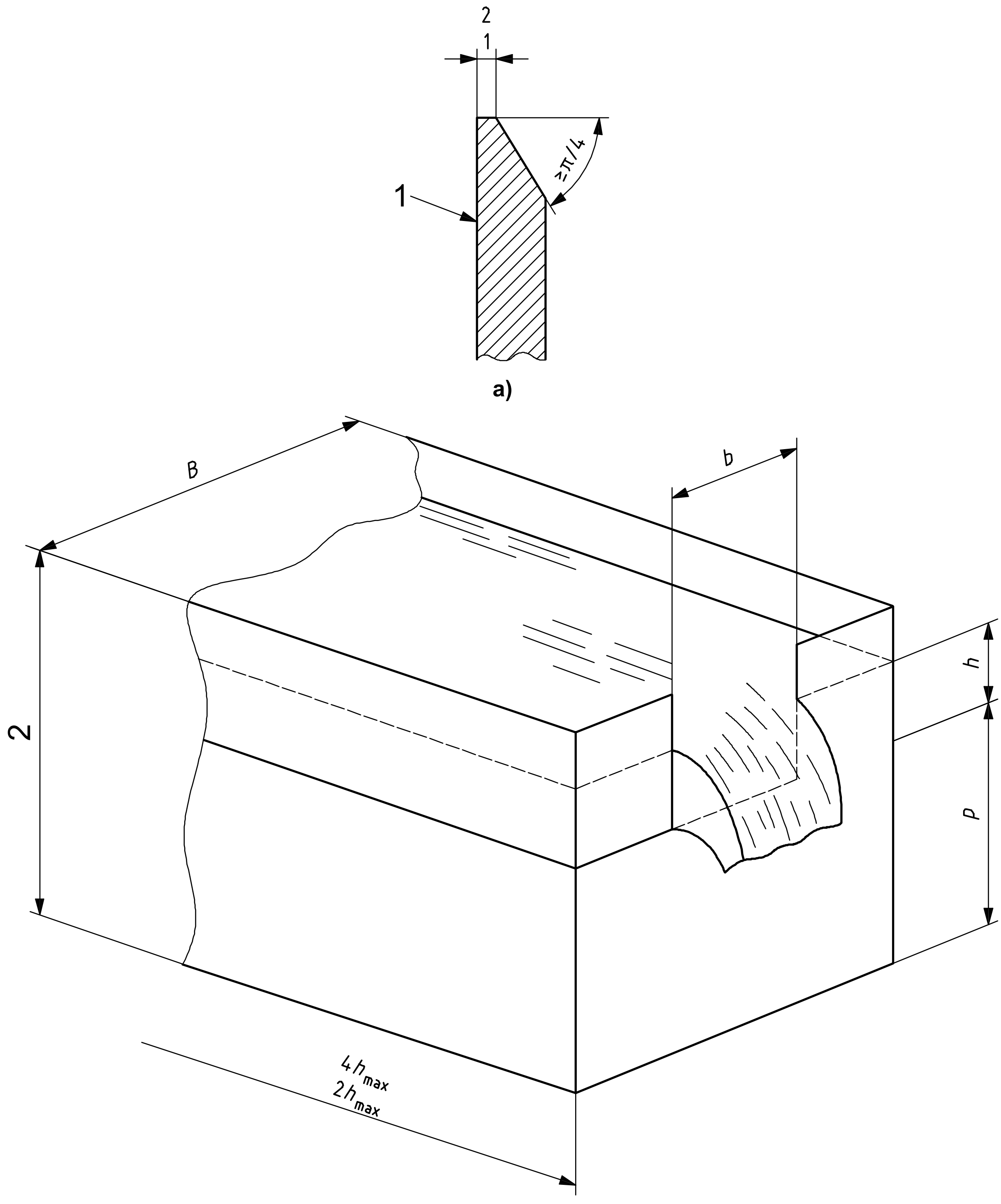
Dimensions in millimetres




a)

b)

**Key**

1 upstream face of weir plate

2 head measurement section, $h_1$

**Figure 2 — Rectangular-notch, thin-plate weir**



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## 9.2 Specifications for the standard weir

The basic weir form consists of a rectangular notch in a vertical, thin plate. The plate shall be plane and rigid and perpendicular to the walls and the floor of the approach channel. The upstream face of the plate shall be smooth (in the vicinity of the notch it shall be equivalent in surface finish to that of rolled sheet-metal).

The vertical bisector of the notch shall be equidistant from the two walls of the channel. The crest surface of the notch shall be a horizontal, plane surface, which shall form a sharp edge at its intersection with the upstream face of the weir plate. The width of the crest surface, measured perpendicular to the face of the plate, shall be between 1 mm and 2 mm. The side surfaces of the notch shall be vertical, plane surfaces which shall make sharp edges at their intersection with the upstream face of the weir plate. For the limiting case of the full-width weir, the crest of the weir shall extend to the walls of the channel, which in the vicinity of the crest shall be plane and smooth (see also 9.3).

To ensure that the upstream edges of the crest and the sides of the notch are sharp, they shall be machined or filed, perpendicular to the upstream face of the weir plate, free of burrs or scratches and untouched by abrasive cloth or paper. The downstream edges of the notch shall be chamfered if the weir plate is thicker than the maximum allowable width of the notch surface. The surface of the chamfer shall make an angle of not less than $\pi/4$ radians (45°) with the crest and side surfaces of the notch (see detail, Figure 2). The weir plate in the vicinity of the notch preferably shall be made of corrosion-resistant metal; but if it is not, all specified smooth surfaces and sharp edges shall be kept coated with a thin, protective film (for example, oil, wax, silicone) applied with a soft cloth.

## 9.3 Specifications for installation

The specifications stated in 6.3 shall apply. In general, the weir shall be located in a straight, horizontal, rectangular approach channel if possible. However, if the effective opening of the notch is so small in comparison with the area of the upstream channel that the approach velocity is negligible, the shape of the channel is not significant. In any case, the flow in the approach channel shall be uniform and steady, as specified in 6.3.3.

If the width of the weir is equal to the width of the channel at the weir section (i.e. a full-width weir), the sides of the channel upstream from the plane of the weir shall be vertical, plane, parallel and smooth (equivalent in surface finish to that of rolled sheet-metal). The sides of the channel above the level of the crest of a full-width weir shall extend at least 0,3 $h_{\text{max}}$ downstream from the plane of the weir. Fully ventilated discharge shall be ensured as specified in 6.3.4.

The approach channel floor shall be smooth, flat and horizontal when the height of the crest relative to the floor ($p$) is small and/or $h/p$ is large. For rectangular weirs, the floor should be smooth, flat and horizontal, particularly when $p$ is less than 0,1 m and/or $h_{\text{max}}/p$ is greater than 1. Additional conditions are specified in connection with the recommended discharge formulae.

## 9.4 Determination of gauge zero

The head-gauge datum or gauge zero shall be determined with great care, and it shall be checked when necessary. A typical, acceptable method of determining the gauge zero for rectangular weirs is described as follows.

a) Still water in the approach channel is drawn to a level below the weir crest.

b) A temporary hook gauge is mounted over the approach channel, a short distance upstream from the weir crest.

c) A precise machinists' level is placed with its axis horizontal, with one end lying on the weir crest and the other end on the point of the temporary hook gauge (the gauge having been adjusted to hold the level in this position). The reading of the temporary gauge is recorded.


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d) The temporary hook gauge is lowered to the water surface in the approach channel and its reading is recorded. The permanent gauge is adjusted to read the level in the gauge well, and this reading is recorded.

e) The computed difference between the two readings of the temporary gauge is added to the reading of the permanent gauge. The sum is the gauge zero for the permanent gauge.

Figure 3 illustrates the use of this procedure with a form of temporary hook gauge which is conveniently mounted on the weir plate.

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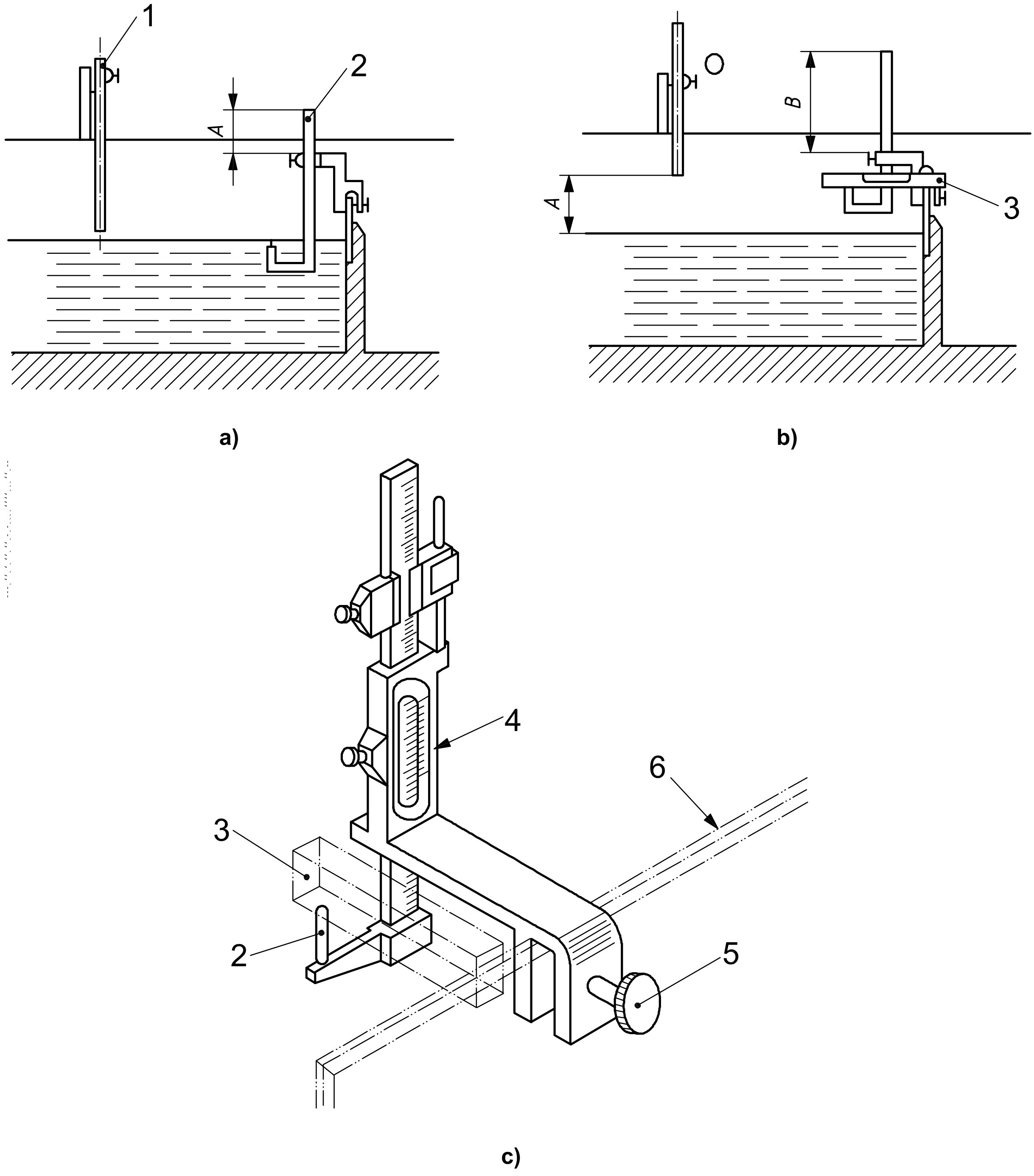


**Key**

1 permanent gauge

2 temporary hook gauge

3 precision level

4 vernier micrometer

5 set screw

6 weir crest

**Figure 3 — Determination of gauge zero for rectangular weir**


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## 9.5 Discharge formulae — General

Recommended discharge formulae for rectangular thin-plate weirs are presented in three categories:

a) modular discharge equation for the basic weir form (all values of $b/B$);

b) modular discharge equation for full-width weirs ($b/B = 1,0$);

c) non-modular discharge equation for full-width weirs.

## 9.6 Formulae for the basic weir form (all values of $b/B$)

### 9.6.1 Kindsvater-Carter formula

The Kindsvater-Carter formula for the basic weir form is:

$$Q = C_d \frac{2}{3} \sqrt{2g} b_e h_e^{3/2} \tag{1}$$

where

$C_d$ is the coefficient of discharge;

$b_e$ is the effective width;

$h_e$ is the effective head.

#### 9.6.1.1 Evaluation of $C_d$, $k_b$ and $k_h$

Figure 4 shows experimentally determined values of $C_d$ as a function of $h/p$ for representative values of $b/B$. Values of $C_d$ for intermediate values of $b/B$ can be determined by interpolation.

The coefficient of discharge $C_d$ has been determined by experiment as a function of two variables from the formula:

$$C_d = f\left(\frac{b}{B}, \frac{h}{p}\right) \tag{2}$$

The effective width and head are defined by Equations (3) and (4):

$$b_e = b + k_b \tag{3}$$

$$h_e = h + k_h \tag{4}$$

in which $k_b$ and $k_h$ are experimentally determined quantities, in metres, which compensate for the combined effects of viscosity and surface tension.



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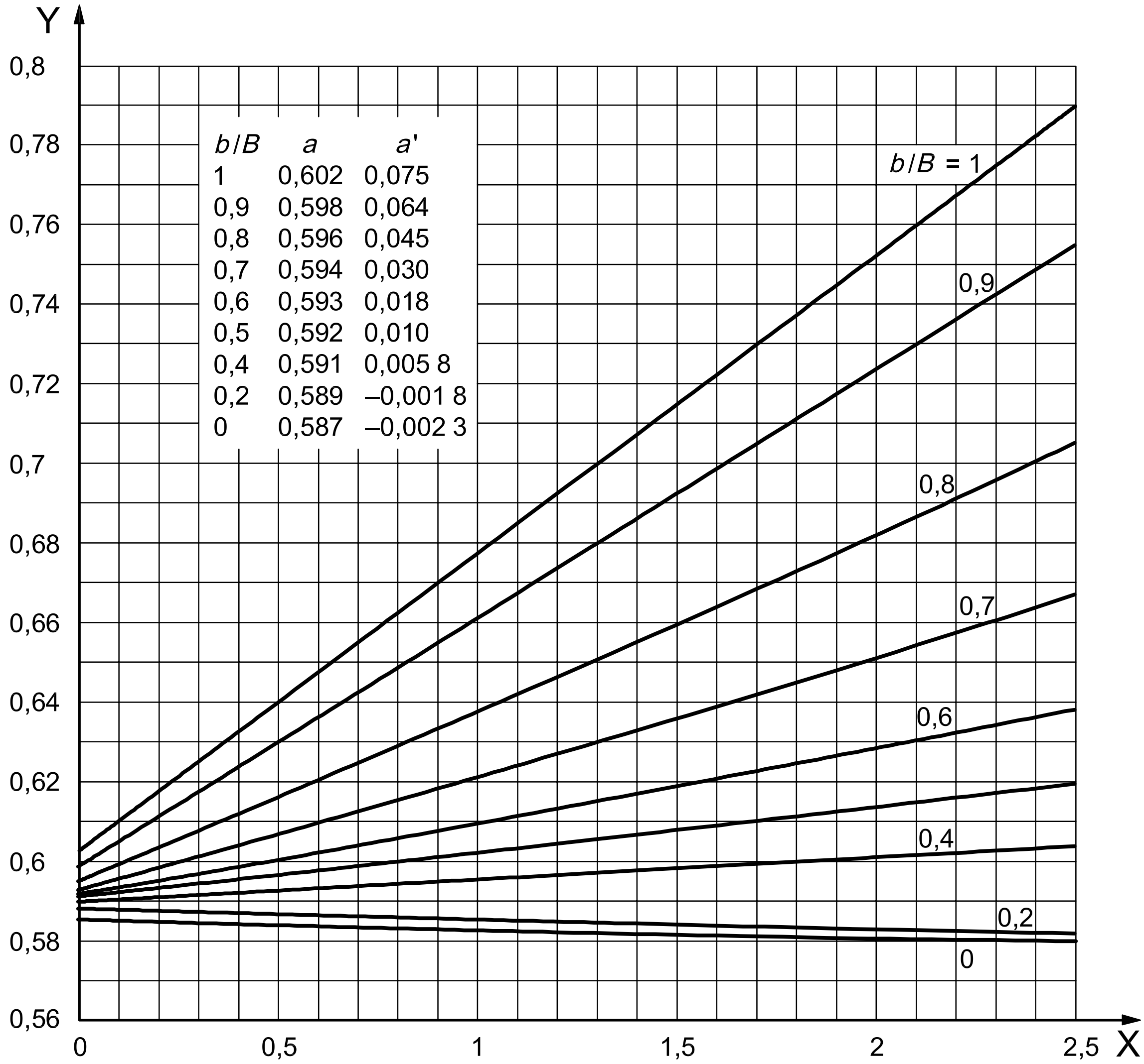


**Key**

X value of $\dfrac{h}{p}$

Y value of $C_\mathrm{d}$

**Figure 4 — Coefficient of discharge** $C_\mathrm{d} = a + a'\left(\dfrac{h}{p}\right)$

Figure 5 shows values of $k_b$, which have been experimentally determined as a function of $b/B$.

Experiments have shown that $k_h$ can be taken to have a constant value of 0,001 m for weirs constructed in strict conformance with recommended specifications.



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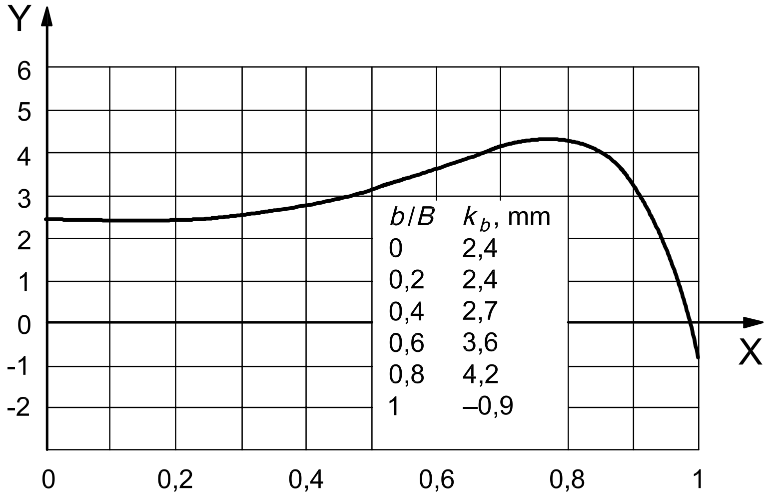


**Key**

X $b/B$

Y $k_b$, in millimetres

**Figure 5 — Value of $k_b$ related to $b/B$**

### 9.6.1.2 Formulae for $C_d$

For specific values of $b/B$, the relationship between $C_d$ and $h/p$ has been shown by experiment (see Figure 4) to be of the linear form $C_d = a + a'\left(\frac{h}{p}\right)$.

Thus, for the values of $b/B$ shown on Figure 4, formulae for $C_d$ can be written as follows:

$$\left(\frac{b}{B} = 1{,}0\right): C_d = 0{,}602 + 0{,}075\frac{h}{p} \tag{5}$$

$$\left(\frac{b}{B} = 0{,}9\right): C_d = 0{,}598 + 0{,}064\frac{h}{p} \tag{6}$$

$$\left(\frac{b}{B} = 0{,}8\right): C_d = 0{,}596 + 0{,}045\frac{h}{p} \tag{7}$$

$$\left(\frac{b}{B} = 0{,}7\right): C_d = 0{,}594 + 0{,}030\frac{h}{p} \tag{8}$$

$$\left(\frac{b}{B} = 0{,}6\right): C_d = 0{,}593 + 0{,}018\frac{h}{p} \tag{9}$$

$$\left(\frac{b}{B} = 0{,}5\right): C_d = 0{,}592 + 0{,}010\frac{h}{p} \tag{10}$$

$$\left(\frac{b}{B} = 0{,}4\right): C_d = 0{,}591 + 0{,}005\,8\frac{h}{p} \tag{11}$$

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$$\left(\frac{b}{B} = 0{,}2\right): C_\mathrm{d} = 0{,}589 + 0{,}001\,8\frac{h}{p} \tag{12}$$

$$\left(\frac{b}{B} = 0\right): C_\mathrm{d} = 0{,}587 + 0{,}002\,3\frac{h}{p} \tag{13}$$

For intermediate values of $b/B$, formulae for $C_\mathrm{d}$ can be determined satisfactorily by interpolation.

#### 9.6.1.3 Practical limitations on $h/p$, $h$, $b$ and $p$

Practical limits are placed on $h/p$ because head-measurement difficulties and errors result from surges and waves which occur in the approach channel at larger values of $h/p$. Limits are placed on $h$ to avoid the "clinging nappe" phenomenon which occurs at very low heads. Limits are placed on $b$ because of uncertainties regarding the combined effects of viscosity and surface tension represented by the quantity of $k_b$ at very small values of $b$. Limits are placed on $p$ and $B - b$ to avoid the instabilities which result from eddies that form in the corners between the channel boundaries and the weir when values of $p$ and $B - b$ are small.

For conservative practice, limitations applicable to the use of the Kindsvater-Carter formulae are:

a) $h/p$ shall be not greater than 2,5;

b) $h$ shall be not less than 0,03 m;

c) $b$ shall be not less than 0,15 m;

d) $p$ shall be not less than 0,10 m;

e) either $(B - b)/2 = 0$ (full width weir) or $(B - b)/2$ shall not be less than 0,10 m (contracted weir).

## 9.7 Formulae for full-width weirs ($b/B = 1{,}0$)

### 9.7.1 Modular flow discharge equation

The Rehbock formula in the form proposed in 1929 is of the effective-head variety:

$$Q = C_\mathrm{d}\frac{2}{3}\sqrt{2g}\; b\; h_{1\mathrm{e}}^{3/2} \tag{14}$$

in which

$$C_\mathrm{d} = 0{,}602 + 0{,}083\frac{h_1}{p} \tag{15}$$

$$h_{1\mathrm{e}} = h_1 + 0{,}001\,2 \tag{16}$$

Practical limitations applicable to the use of the Rehbock formula are:

a) $h_1/p$ shall be not greater than 4,0;

b) $h_1$ shall be between 0,03 and 1,0 m;

c) $b$ shall be not less than 0,30 m;

d) $p$ shall be not less than 0,06 m.



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### 9.7.2 Non-modular flow discharge equation

Submerged (drowned) flow occurs when the tailwater level downstream from a weir affects the flow. The weir operates in the non-modular condition. For this condition, an additional downstream measurement of head ($h_2$) is required and a drowned flow reduction factor ($f$) is applied to the modular discharge equation.

Since the modular limit of a full-width thin-plate weir is significantly influenced by the ratio $h_1/P$, the modular limit increasing with $h_1/P$, drowned flow performance of the typical full-width thin-plate weir is shown in Figure 6 and defined by the equations below:

For $h_1/p = 0{,}5$, then $f = 1{,}007\,[0{,}975 - (h_2/h_1)^{1{,}45}]^{0{,}265}$ in the range $0{,}00 < h_2/h_1 < 0{,}97$

For $h_1/p = 1{,}0$, then $f = 1{,}026\,[0{,}960 - (h_2/h_1)^{1{,}55}]^{0{,}242}$ in the range $0{,}20 < h_2/h_1 < 0{,}97$

For $h_1/p = 1{,}5$, then $f = 1{,}098\,[0{,}952 - (h_2/h_1)^{1{,}75}]^{0{,}220}$ in the range $0{,}50 < h_2/h_1 < 0{,}97$

For $h_1/p = 2{,}0$, then $f = 1{,}155\,[0{,}950 - (h_2/h_1)^{1{,}85}]^{0{,}219}$ in the range $0{,}63 < h_2/h_1 < 0{,}97$

Thus, the Rehbock formula (1929) for drowned flow becomes:

$$Q = fC_\mathrm{d}\frac{2}{3}\sqrt{2g}\;b\;h_{1\mathrm{e}}^{3/2} \tag{17}$$

NOTE This adjustment only applies where the upstream and downstream measurements are in the same horizontal plane, i.e. there is no drop in the channel bottom at, or downstream, of the weir.

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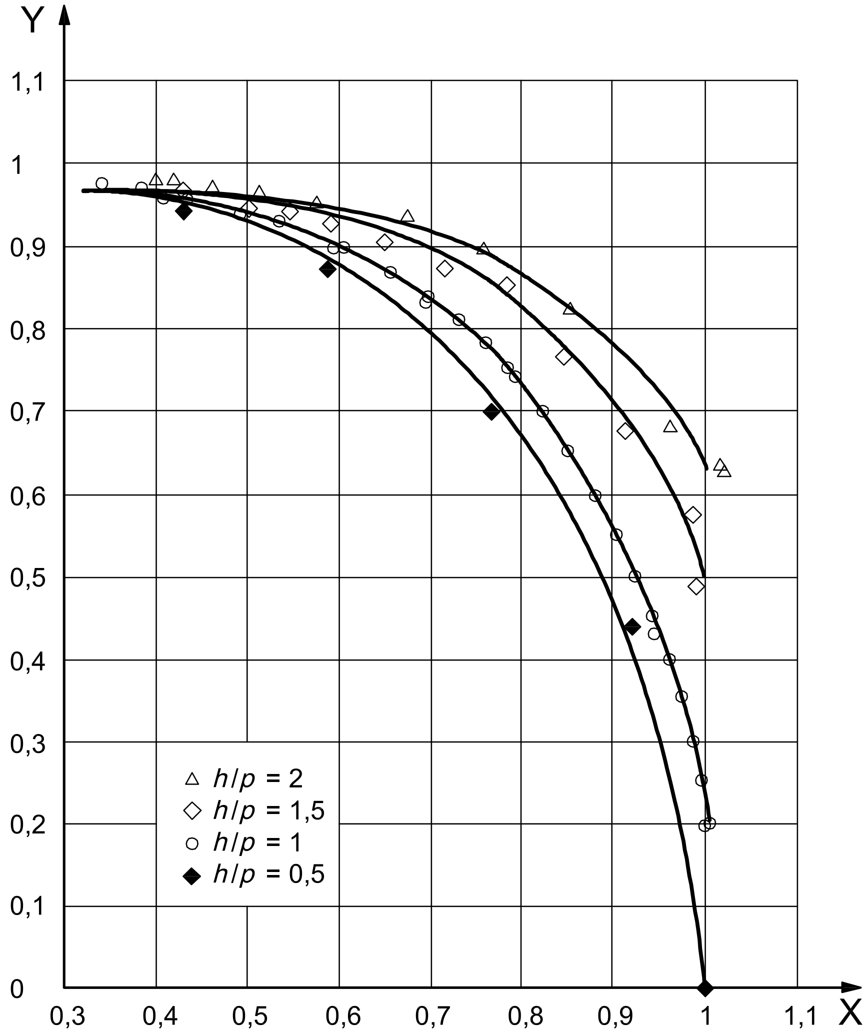


**Key**

X value of $\frac{h_2}{h_1}$

Y value of $f$

**Figure 6 — Drowned flow performance of the full-width thin-plate weir**

## 10 Triangular-notch thin-plate weir

### 10.1 Specifications for the standard weir

The triangular-notch thin-plate weir consists of a V-shaped notch in a vertical, thin plate. A diagrammatic illustration of the triangular-notch weir is shown in Figure 7. The weir plate shall be plane and rigid and perpendicular to the walls and the floor of the channel. The upstream face of the plate shall be smooth (in the vicinity of the notch, it shall be equivalent in surface finish to that of rolled sheet-metal).

The bisector of the notch shall be vertical and equidistant from the two walls of the channel. The surfaces of the notch shall be plane surfaces, which shall form sharp edges at their intersection with the upstream face of the weir plate. The width of the notch surfaces, measured perpendicular to the face of the plate, shall be between 1 mm and 2 mm.

To ensure that the upstream edges of the notch are sharp, they shall be machined or filed, perpendicular to the upstream face of the plate, free of burrs or scratches and untouched by abrasive cloth or paper. The



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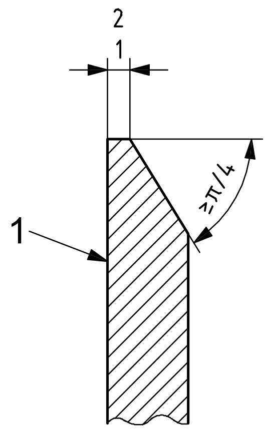
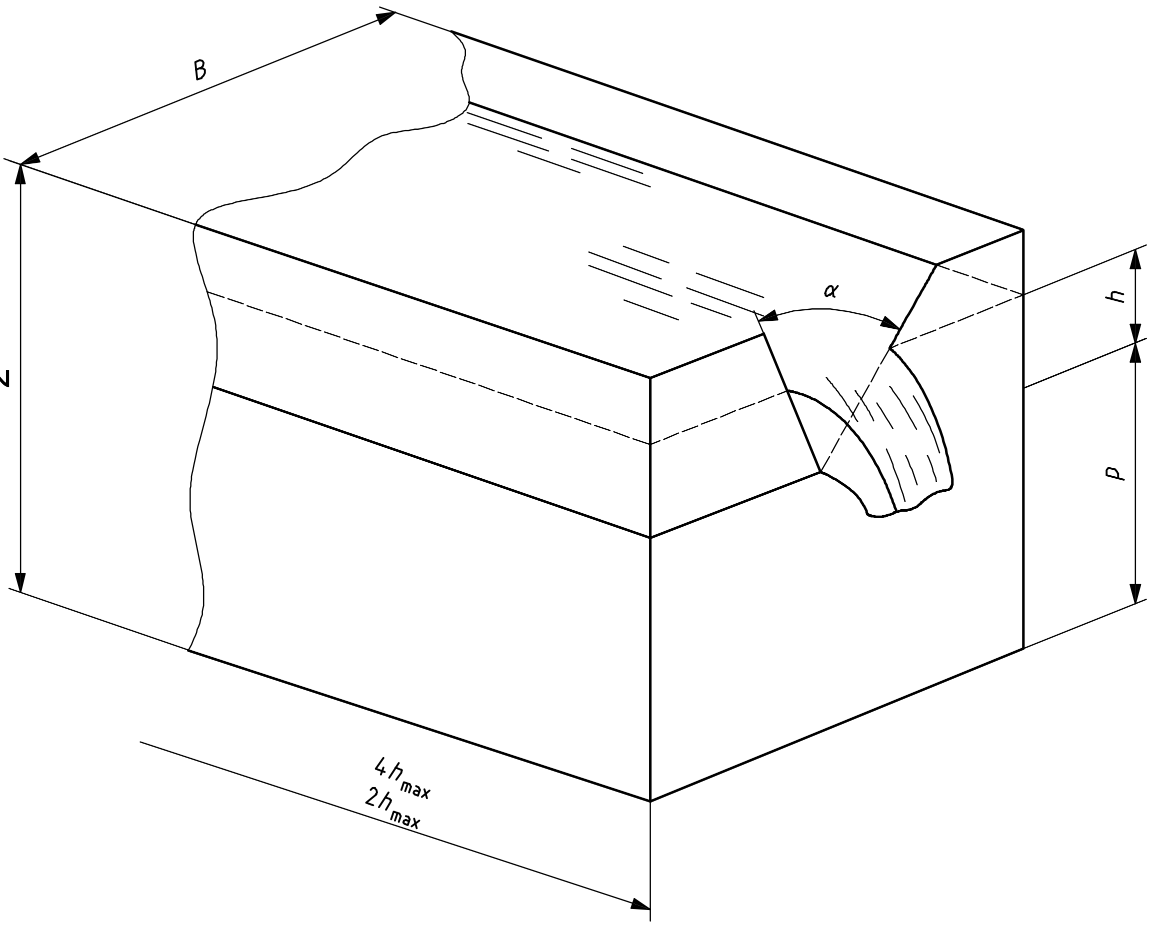
downstream edges of the notch shall be chamfered if the weir plate is thicker than the maximum allowable width of the notch surface. The surface of the chamfer shall make an angle of not less than $\pi/4$ radians (45°) with the surface of the notch (see detail, Figure 7). The weir plate in the vicinity of the notch preferably shall be made of corrosion-resistant metal; but if it is not, all specified smooth surfaces shall be kept coated with a thin protective film (for example, oil, wax, silicone) applied with a soft cloth.

Dimensions in millimetres




a)




b)

**Key**

1 upstream face of weir plate

2 head measurement section

**Figure 7 — Triangular-notch thin-plate weir**

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## 10.2 Specifications for the installation

The specifications stated in 6.3 shall apply. In general, the weir shall be located in a straight, horizontal, rectangular channel if possible. However, if the effective opening of the notch is so small in comparison with the area of the upstream channel that the approach velocity is negligible, the shape of the channel is not significant. In any case, the flow in the approach channel shall be uniform and steady, as specified in 6.3.3.

If the top width of the nappe at maximum head is large in comparison with the width of the channel, the channel walls shall be straight, vertical and parallel. If the height of the vertex relative to the level of the floor is small in comparison with the maximum head, the channel floor shall be smooth, flat and horizontal. In general, the approach channel should be smooth, straight and rectangular when $B/b_{max}$ is less than 3 and/or $h_{max}/p$ is greater than 1. Additional conditions are specified in connection with the recommended discharge formulae.

## 10.3 Specifications for head measurement

### 10.3.1 General

The conditions specified in 7.1, 7.2 and 7.3 shall apply without exception.

### 10.3.2 Determination of notch angle

Precise head measurements for triangular-notch weirs require that the notch angle (angle included between sides of the notch) be measured accurately. One of several satisfactory methods is described as follows.

a) Two true disks of different, micrometered diameters are placed in the notch with their edges tangent to the sides of the notch.

b) The vertical distance between the centres (or two corresponding edges) of the two disks is measured with a micrometer caliper.

c) The notch angle $\alpha$ is twice the angle whose sine is equal to the differences between the radii of the disks divided by the distance between the centres of the disks.

### 10.3.3 Determination of gauge zero

The head-gauge datum or gauge zero shall be determined with great care, and it shall be checked when necessary. A typical acceptable method of determining the gauge zero for triangular notch weirs is described as follows.

a) Still water in the approach channel is drawn to a level below the vertex of the notch.

b) A temporary hook gauge is mounted over the approach channel, with its point a short distance upstream from the vertex of the notch.

c) A true cylinder of known (micrometered) diameter is placed with its axis horizontal, with one end resting in the notch and the other end balanced on the point of the temporary hook gauge. A machinists' level is placed on top of the cylinder, and the hook gauge is adjusted to make the cylinder precisely horizontal. The reading of the temporary gauge is recorded.

d) The temporary hook gauge is lowered to the water surface in the approach channel and the reading is recorded. The permanent gauge is adjusted to read the level in the gauge well, and this reading is recorded.

e) The distance ($y$) from the top of the cylinder to the vertex of the notch is computed with the known value of the notch angle ($\alpha$) and the radius ($r$) of the cylinder $\left[ y = \left( r / \sin\frac{\alpha}{2} \right) + r \right]$. This distance is then


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subtracted from the reading recorded in c), the result being the reading of the temporary gauge at the vertex of the notch.

f) The difference between the computed reading in e) and the reading of the temporary gauge in d) is added to the reading of the permanent gauge in d). The sum is the gauge zero for the permanent gauge.

An advantage of this method is that it refers the gauge zero to the geometrical vertex which is defined by the sides of the notch.

## 10.4 Discharge formulae — General

Recommended discharge formulae for triangular-notch thin-plate weirs are presented in two categories:

a) formula for all notch angles between π/9 and 5π/9 radians (20° and 100°);

b) formulae for specific notch angles (fully contracted weirs).

## 10.5 Formula for all notch angles between π/9 and 5 π/9 radians (20° and 100°)

### 10.5.1 Kindsvater-Shen formula

The Kindsvater-Shen formula for triangular notch weirs is

$$Q = C_{\mathrm{d}} \frac{8}{15} \tan\frac{\alpha}{2} \sqrt{2g}\, h_{\mathrm{e}}^{5/2} \tag{18}$$

where

$C_{\mathrm{d}}$ is the coefficient of discharge;

$h_{\mathrm{e}}$ is the effective head.

The coefficient of discharge $C_{\mathrm{d}}$ has been determined by experiment as a function of three variables (see Figure 8).

$$C_{\mathrm{d}} = f\left(\frac{h}{p}, \frac{p}{B}, \alpha\right) \tag{19}$$

where

$p$ is the height of the vertex of the notch with respect to the floor of the approach channel;

$B$ is the width of the approach channel;

$h_{\mathrm{e}}$ is defined by Equation (20):

$$h_{\mathrm{e}} = h + k_h \tag{20}$$

in which $k_h$ is an experimentally determined quantity, in metres, which compensates for the combined effects of viscosity and surface tension.

### 10.5.2 Evaluation of $C_{\mathrm{d}}$ and $k_h$

For triangular weirs with notch angle $\alpha$ equal to π/2 radians (90°), Figure 8 shows experimentally determined values of $C_{\mathrm{d}}$ for a wide range of values of $h/p$ and $p/B$. For $\alpha = \pi/2$ radians (90°), $k_h$ has been shown to have a constant value of 0,000 85 m for a corresponding range of values of $h/p$ and $p/B$.

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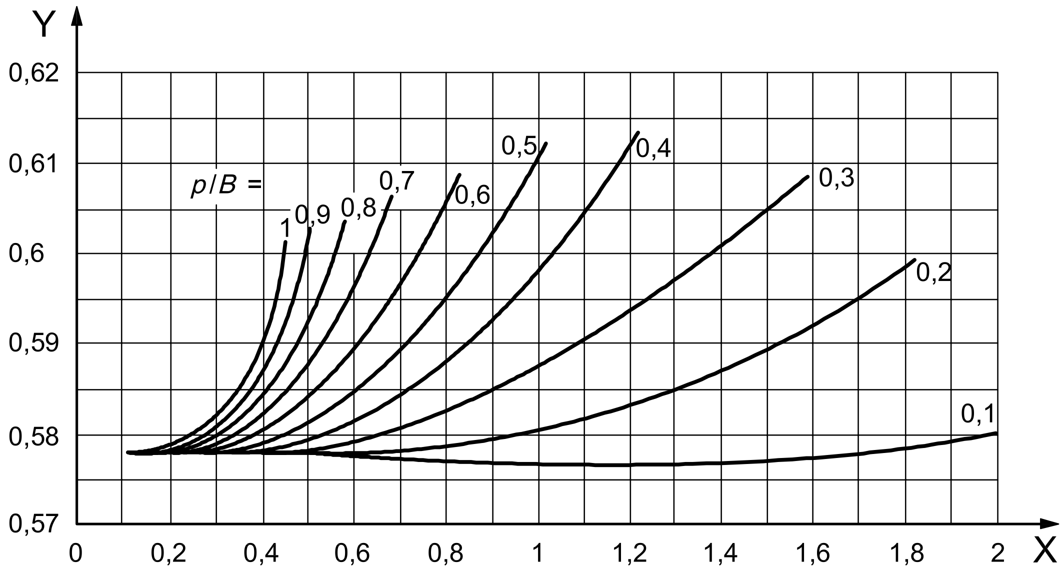
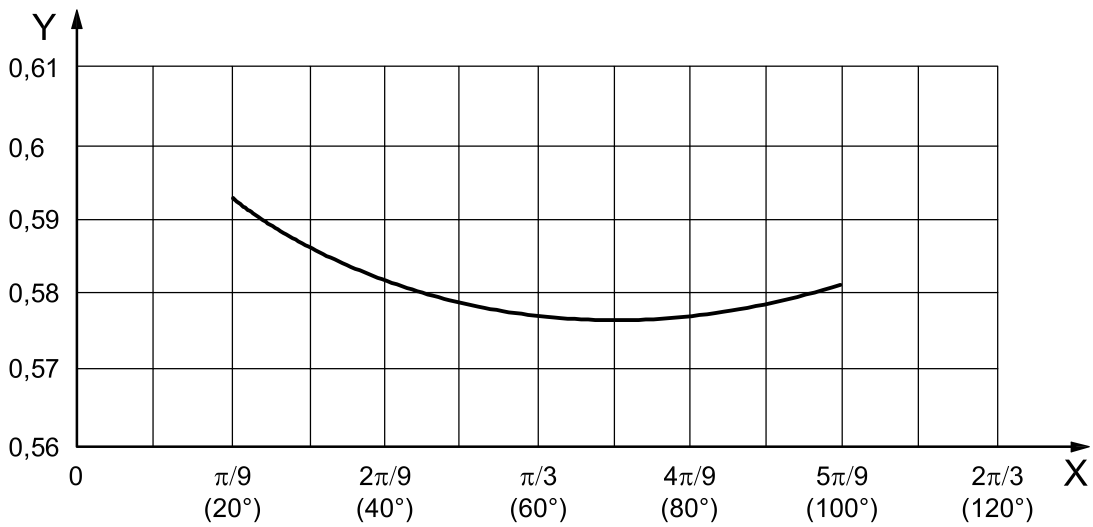



**Key**

X value of $\frac{h}{p}$

Y value of $C_d$

**Figure 8 — Coefficient of discharge,** $C_d$ ($\alpha = 90°$)




**Key**

X value of notch angle, $\alpha$ (radians)

Y value of $C_d$

**Figure 9 — Coefficient of discharge $C_d$ related to notch angle $\alpha$**

For notch angles other than $\pi/2$ radians (90°), experimental data are insufficient to define $C_d$ as a function of $h/p$ and $p/B$. However, for weir notches which are small relative to the area of the approach channel, the velocity of approach is negligible and the effects of $h/p$ and $p/B$ are also negligible. For this condition (the so-called “fully-contracted” condition), Figure 9 shows experimentally determined values of $C_d$ as a function of $\alpha$ alone. Corresponding values of $k_h$ are shown in Figure 10.



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### 10.5.3 Practical limitations on $\alpha$, $h/p$, $p/B$, $h$ and $p$

For reasons related to hazards of measurement-error and lack of experimental data, the following practical limits are applicable to use of the Kindsvater-Shen formula:

a) $\alpha$ shall be between $\pi/9$ and $5\ \pi/9$ radians (20° and 100°);

b) $h/p$ shall be limited to the range shown on Figure 8 for $\alpha = \pi/2$ radians (90°); $h/p$ shall be not greater than 0,35 for other values of $\alpha$;

c) $h$ shall be not less than 0,06 m;

d) $p$ shall be not less than 0,09 m.

## 10.6 Formula for specific notch angles (fully-contracted weir)

The BSI [1)] equation is for three notch angles that have a special geometric relationship to each other:

a) tangent $\alpha/2 = 1$ ($\alpha = \pi/2$ radians or 90°);

b) tangent $\alpha/2 = 0{,}50$ ($\alpha = 0{,}927\ 3$ radian or 53° 8′);

c) tangent $\alpha/2 = 0{,}25$ ($\alpha = 0{,}489\ 9$ radian or 28° 4′).

The BSI discharge formula is:

$$Q = C \frac{8}{15} \tan \frac{\alpha}{2} \sqrt{2g}\, h_{\mathrm{e}}^{5/2} \qquad (21)$$

and the experimentally determined values of $C$ and $Q$ for the condition of “full contraction” are shown in Tables E.1, E.2 and E.3.

Practical limitations applicable to the use of this formula are:

a) $h/p$ shall be not greater than 0,4;

b) $h/B$ shall be not greater than 0,2;

c) $h$ shall be between 0,05 and 0,38 m;

d) $p$ shall be not less than 0,45 m;

e) $B$ shall be not less than 1,0 m.

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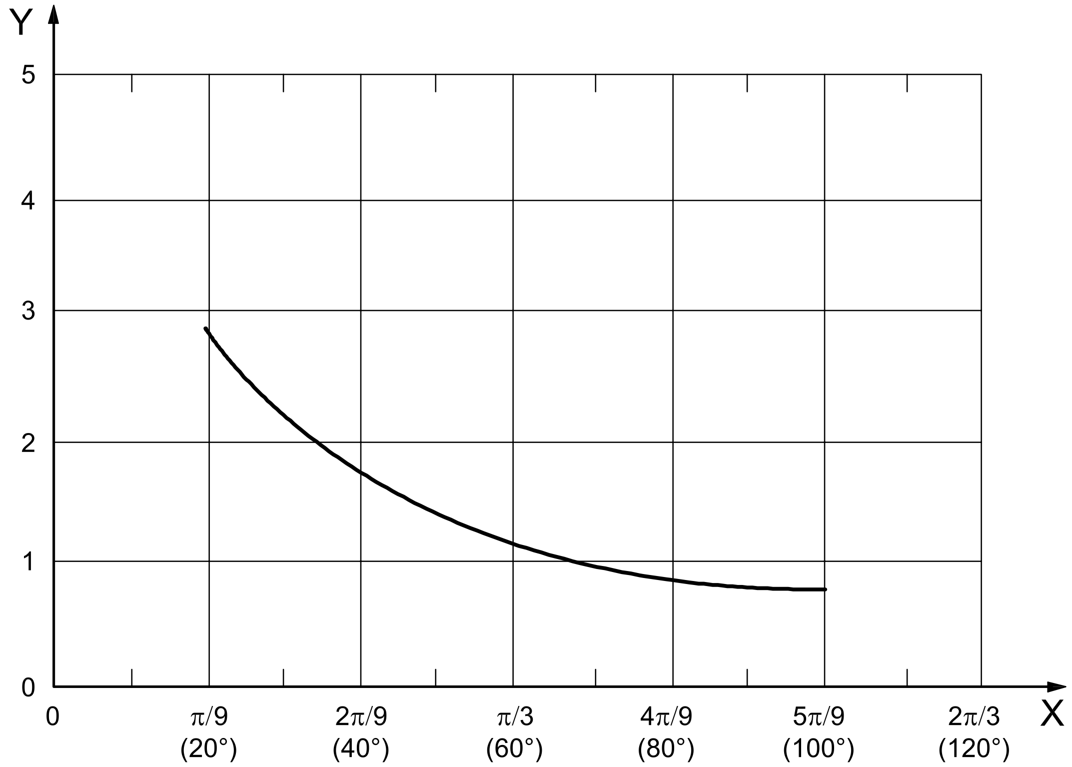


**Key**

X notch angle $\alpha$

Y $k_h$, in millimetres

**Figure 10 — Value of $k_h$ related to notch angle $\alpha$**

### 10.7 Accuracy of discharge coefficients — Triangular-notch weirs

The accuracy of discharge measurements made with a triangular-notch thin-plate weir depends primarily on the accuracy of the head and notch-angle measurements and on the applicability of the discharge formula and coefficients used. If great care is exercised in meeting the construction, installation, and operational conditions specified in this International Standard, uncertainties (at 95 % confidence level) attributable to the coefficients of discharge will be not greater than 1,0 %. The combination of all uncertainties which contribute significantly to the uncertainty of discharge measurements is treated in Clause 11. Examples of estimated uncertainties in measured discharge are given in Clause 12.

## 11 Uncertainties of flow measurement

### 11.1 General

**11.1.1** This clause provides information for the user of this International Standard to state the uncertainty of a measurement of discharge.

**11.1.2** Annex C is an introduction to measurement uncertainty. It provides supporting information based on the *Guide to the expression of uncertainty in measurement* (hereafter referred to as the GUM)[5] and ISO/TS 25377 (hereafter referred to as the HUG)[4]. Refer to Annex C for definitions.

Former versions of this International Standard have expressed the uncertainty of discharge coefficient $u(C)$ at the 95 % level of confidence. This is equivalent to two standard deviations, or twice the value of standard uncertainty.


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This version of ISO 1438-1, expresses discharge coefficient as standard uncertainty (one standard deviation) to be in accordance with the GUM.

Hydrometry requires measurements using various techniques, the results of which are used to calculate a value for flow. Annex D provides sample values for the various techniques. These are presented in tabular form with uncertainty estimates ascribed to each technique for the purpose of illustration only.

These sample values are not to be interpreted as norms of performance.

The example given in Clause 12 uses values from Annex D.

**11.1.3** A measurement result comprises

i) an estimate of the measured value, with

ii) a statement of the uncertainty of the measurement.

**11.1.4** A statement of the uncertainty of a flow measurement in a channel has four separate components of uncertainty:

i) uncertainty of the measurement of head in the channel;

ii) uncertainty of the dimensions of the structure;

iii) uncertainty of the discharge coefficient stated in this International Standard from laboratory calibration of the flow structure being considered;

iv) uncertainty of channel velocity distribution related to the velocity coefficient, $C_v$.

This clause does not accommodate component iv). It is assumed that the channel hydraulics are substantially equivalent to those existing in the calibration facility at the time of derivation of component iii) as defined in 6.3.3.

**11.1.5** The estimation of measurement uncertainty associated with items i) and ii) of 11.1.4 is provided in Annex D.

Values taken from Annex D are used in the examples in Clause 12. These values are for illustrative purposed only, they should not be interpreted as norms of performance for the types of equipment listed. In practice, uncertainty estimates should be taken from test certificates for the equipment, preferably obtained from laboratories which are accredited to ISO/IEC 17025.

## 11.2 Combining measurement uncertainties

Refer to Clause C.7.

The proportion in which each flow equation parameter contributes to flow measurement uncertainty, $U(Q)$, is derived by analytical solution using partial differentials of the discharge equation.

For this purpose, the equations for rectangular and triangular forms have been simplified to:

$$Q_\mathrm{r} = J_\mathrm{r}\sqrt{g}\ C_\mathrm{d}\ b_\mathrm{e}\ h_\mathrm{e}^{1,5} \tag{22}$$

$$Q_\mathrm{t} = J_\mathrm{t}\sqrt{g}\ C_\mathrm{d}\ \tan\frac{\alpha}{2}\ h_\mathrm{e}^{2,5} \tag{23}$$

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where $J$ is a numerical constant, dependent on the form of weir but not subject to error. The subscripts r and t denote the rectangular form and the triangular form of weir, respectively. From Equations (22) and (23), the dispersion of the value $Q$ of the equation can be written:

$$\Delta Q_{\mathrm{r}} = J_{\mathrm{r}}\sqrt{g}\left(\frac{\partial Q_{\mathrm{r}}}{\partial C_{\mathrm{d}}}\Delta C_{\mathrm{d}} + \frac{\partial Q}{\partial b_{\mathrm{e}}}\Delta b_{\mathrm{e}} + \frac{\partial Q}{\partial h_{\mathrm{e}}}\Delta h_{\mathrm{e}}\right) \tag{24}$$

$$\Delta Q_{\mathrm{t}} = J_{\mathrm{t}}\sqrt{g}\left(\frac{\delta Q_{\mathrm{t}}}{\delta C_{\mathrm{d}}}\Delta C_{\mathrm{d}} + \frac{\partial Q_{\mathrm{t}}}{\delta \tan\left(\frac{\alpha}{2}\right)}\Delta \tan\left(\frac{\alpha}{2}\right) + \frac{\partial Q_{\mathrm{t}}}{\delta h_{\mathrm{e}}}\Delta h_{\mathrm{e}}\right) \tag{25}$$

where the partial derivatives are the sensitivity coefficients described in the HUG and where $\Delta Q$ is the dispersion of $Q$ due to small dispersions of $\Delta C$, $\Delta b$ or $\Delta \tan\left(\frac{\alpha}{2}\right)$ and $\Delta h_{\mathrm{e}}$. Evaluating the partial differentials and using Equations (22) and (23), the relationship can be written:

$$\frac{\Delta Q_{\mathrm{t}}}{Q_{\mathrm{t}}} = \frac{\Delta C_{\mathrm{d}}}{C_{\mathrm{d}}} + \frac{\Delta b_{\mathrm{e}}}{b_{\mathrm{e}}} + 1{,}5\frac{\Delta h_{\mathrm{e}}}{h_{\mathrm{e}}} \tag{26}$$

$$\frac{\Delta Q_{\mathrm{t}}}{Q_{\mathrm{t}}} = \frac{\Delta C_{\mathrm{d}}}{C_{\mathrm{d}}} + \frac{\Delta \tan\frac{\alpha}{2}}{\tan\frac{\alpha}{2}} + 2{,}5\frac{\Delta h_{\mathrm{e}}}{h_{\mathrm{e}}} \tag{27}$$

In uncertainty analysis, the values $\frac{\Delta Q}{Q}, \frac{\Delta b}{b}, \frac{\Delta C}{C}, \frac{\Delta \tan\frac{\alpha}{2}}{\tan\frac{\alpha}{2}}$ and $\frac{\Delta h}{h}$ are referred to as dimensionless standard uncertainties and have the notation $u^*(Q)$, $u^*(C)$, $u^*(b)$, $u^*\left[\tan\left(\frac{\alpha}{2}\right)\right]$ and $u^*(h)$.

Note, the value $u^*\left[\tan\left(\frac{\alpha}{2}\right)\right]$ is derived from the relationship:

$$\tan\left(\frac{\alpha}{2}\right) = \frac{b_{\mathrm{t}}}{2h_{\mathrm{t}}} \tag{28}$$

where $b_{\mathrm{t}}$ is the crest width and $h_{\mathrm{t}}$ is the height of the notch.

Since the uncertainties of $b$, $\alpha$, $C$ and $h$ are independent of each other, probability requires summation in quadrature rather than a simple summation.

$$u_{\mathrm{c}}^*(Q)_{\mathrm{r}} = \sqrt{u^*(C_{\mathrm{d}})^2 + u^*(b_{\mathrm{e}})^2 + \left[1{,}5u^*(h_{\mathrm{e}})\right]^2} \tag{29}$$

$$u_{\mathrm{c}}^*(Q)_{\mathrm{t}} = \sqrt{u^*(C_{\mathrm{d}})^2 + u^*\left[\tan\left(\frac{\alpha}{2}\right)\right]^2 + \left[2{,}5u^*(h_{\mathrm{e}})\right]^2} \tag{30}$$


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### 11.3 Uncertainty of discharge coefficient $u^*(C_d)$ for thin-plate weirs

The discharge coefficient $C_d$ of Clauses 9 and 10 have been determined from a series of hydraulics tests using a high resolution calibration facility. From these tests, the values of discharge coefficient uncertainty, $u^*(C_d)$, are summarized in Table 2.

**Table 2 — Values of discharge coefficient uncertainty, $u^*(C_d)$, against head, $h$**

| Type | Head, $h$ | $u^*(C_d)$ |
|---|---|---|
| Rectangular | $h < 1{,}0p$ | 0,75 % |
| Rectangular | $1{,}0p < h < 1{,}5p$ | 1,00 % |
| Rectangular | $1{,}5p < h < 2{,}5\,p$ | 1,50 % |
| Triangular | — | 0,5 % |

### 11.4 The uncertainty budget

In reports, an uncertainty budget table may be presented (or referenced) to provide the following information for each source of uncertainty:

a) the method of evaluation (from Annex C);

b) the determined value of standard uncertainty $u^*(C_d)$, $u^*\left[\tan\left(\frac{\alpha}{2}\right)\right]$ and $u^*(h_e)$ including datum uncertainly of $u^*(h_e)$;

c) the relative sensitivity coefficients, Equations (26) and (27).

The values for each source are then applied according to Equation (29) or Equation (30) to give the combined standard uncertainty, $u^*(Q)$.

The expanded uncertainty $U^*(Q)$ for a confidence level of 95 % is calculated using Table C.1.

It is customary to present these steps in tabular form with one row for each source and a column for each of the items a) to c) above.

The table may include, where appropriate, the critical thinking behind the subjective allocation of uncertainty to the quantities $b$ and $h$. This section of the table may be replicated for a range of values of $h_1$ to determine a relationship between $u^*(Q)$ and $h_1$.

## 12 Example

### 12.1 General

In presenting examples, the equations given in Clauses 9 and 10 define the relationship between the parameters which determine flow rate.

Uncertainty of the discharge coefficient is a fundamental uncertainty and is defined in 11.3. To complete an overall uncertainty estimation, practical estimations shall be made of the head measurement uncertainty and the uncertainty of the measurement of physical dimensions.

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Annex D provides a consistent framework for evaluating these uncertainties for the commonly used measurement techniques.

One such technique is selected in 12.3 for the example that follows.

## 12.2 Characteristics — Gauging structure

The example relates to modular flow conditions for a 90° V-notch weir. The crest height $p$ above the bed of the approach channel is 0,151 m. The channel is 0,503 m wide. The angle of the V-notch is estimated to lie between 89,5° and 90,5°.

## 12.3 Characteristics — Gauged head instrumentation

In this example, a pressure transducer is used to determine head. The transducer is located in the approach channel about 1 m upstream of the weir.

i) The signal indicates a head of 0,212 m. Referring to Annex D, the measurement uncertainty from the table, at this head, is $u(h_1) = 0{,}002$ m.

ii) The transducer is susceptible to drift over a period of time. Over a period of time, it has been noted that the nominal datum signal varies in the range 0,000 m to 0,007 m. Datum uncertainty is estimated according to the rectangular distribution Equation (C.5).

$$u(E) = \frac{1}{\sqrt{3}}\left(\frac{0{,}007 - 0{,}000}{2}\right)$$

$$u(E) = 0{,}002 \text{ m}$$

## 12.4 Discharge coefficient

The value of the gauged head discharge coefficient is determined from Figure 8 for the 90° V-notch weir. The key ratios of $h/p$ and $p/B$ are:

$$\frac{h}{p} = \frac{0{,}212}{0{,}151} = 1{,}40$$

$$\frac{p}{B} = \frac{0{,}151}{0{,}503} = 0{,}30$$

From which $C_d = 0{,}600$.

## 12.5 Discharge estimate

The flow rate is calculated from Equation (18):

$$Q_t = C_d \frac{8}{15} \tan\frac{\alpha}{2} \sqrt{2g} h_e^{5/2}$$

where $h_e = h + k_h = 0{,}212 + 0{,}000\ 85$

$$Q_t = 0{,}600 \times 0{,}533\ 3 \times 4{,}429 \times 1 \times 0{,}212\ 85^{2{,}5}$$

$$\therefore Q_t = 0{,}029\ 6 \text{ m}^3/\text{s}$$



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## 12.6 Uncertainty statement

**12.6.1** From Table 2, the value for uncertainty of the discharge coefficient is:

$$u^*(C) = 0{,}50\ \%$$

**12.6.2** Using Equation (C.4), the value of uncertainty of the V-angle may be written:

$$u\left[\tan\left(\frac{\alpha}{2}\right)\right] = \frac{1}{\sqrt{6}}\left[\frac{\tan\left(\frac{90{,}5}{2}\right) - \tan\left(\frac{89{,}5}{2}\right)}{2}\right]$$

$$= 0{,}003\ 6$$

or $u^*\left[\tan\left(\frac{\alpha}{2}\right)\right] = 100 \times \frac{0{,}003\ 6}{\tan\left(\frac{90}{2}\right)} = 0{,}36\ \%$

**12.6.3** The combined uncertainty of gauged head $u(h)$, calculated in 12.3, is combined with instrumentation measurement uncertainty and datum measurement uncertainty.

$$u(h) = \sqrt{(0{,}002)^2 + (0{,}002)^2}\ \text{m}$$

$$u(h) = 0{,}002\ 8\ \text{m}$$

$$u^*(h) = \frac{0{,}002\ 8}{0{,}212} \times 100$$

$$u^*(h) = 1{,}32\ \%$$

**12.6.4** The combined uncertainty estimate is determined from Equation (30).

$$u_c^*(Q) = \sqrt{u^*(C_e)^2 + u^*\left[\tan\left(\frac{\alpha}{2}\right)\right]^2 + \left[2{,}5u^*(h_e)\right]^2}$$

$$u_c^*(Q) = \sqrt{0{,}50^2 + 0{,}36^2 + (2{,}5 \times 1{,}32)^2}$$

$$u_c^*(Q) = 3{,}35\ \%$$

Therefore, at the 95 % confidence level:

$$u_c^*(Q) = 3{,}35 \times 2 = 6{,}7\ \%$$

NOTE This estimate is dominated by the contribution from head measurement uncertainty and assumes sufficient measurement samples.

**12.6.5** The conventional statement of discharge is therefore:

0,029 3 $m^3/s$ with an uncertainty of 6,7 % at the 95 % level of confidence based on a coverage factor of $k = 2$.

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**12.6.6** The uncertainty budget for the example could be expressed as in Table 3.

**Table 3 — Uncertainty budget for the example**

| | Type/ Evaluation | $u$, $u^*$ Value | Sensitivity coefficients | Comment |
|---|---|---|---|---|
| $u^*(C_d)$ | B/Normal | 0,5 % | 1,0 | From laboratory tests |
| $u^*[\tan(\alpha/2)]$ | B/Triangular | 0,36 % | 1,0 | Using C.6.2 |
| $u(E)$ | B/Rectangular | 0,002 m | — | Using C.6.3 |
| $u(h_1)$ | B/Rectangular | 0,002 m | — | From Table D.1 |
| $u^*(h_1)$ | Combined | 1,32 % | 2,5 | From 12.6.3 |
| $u_c^*(Q)$ | Combined | 3,35 % | — | Using Equation (6) |


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# Annex A
(informative)

## Flow measurement with small weir tanks

Whenever possible, weir tanks conforming to 6.3.3 should be used to measure flow in the field. When the highest accuracy is not required or where site conditions make it difficult to install or operate large tanks satisfactorily, smaller tanks may be used.

There is a limited amount of data on how the discharge coefficients of weirs are affected by the size of the tank, as well as by non-standard head-measuring positions, asymmetric and unsteady flow conditions at entry and sediment deposits. Further information can be obtained from *The performance of weir tanks fitted with V-notch and rectangular thin-plate weirs* [2)].

In order to give some guide to the effect that a reduction in the size of the weir tank will have, values of the discharge coefficient have been tabulated for seven different sizes of weir tank. Table A.1 gives values of $C$ in the BSI formula for a 90° V-notch and of $C_d$ in the Kindsvater-Carter formula for a contracted rectangular-notch.

Some indication of the influence of sediment deposit is given in Table A.2, which shows values of $C_d$ for a tank with dimensions conforming to 6.3.3 but with differing amounts of sediment deposited against the weir plate. The uncertainty of these coefficients is approximately 1 %.

Within the range of tank sizes and heads covered in Table A.1, the location of the head-measuring device is relatively unimportant. Positions between 100 mm and 720 mm upstream of the weir produce discharge coefficients which vary by less than 0,5 %. Heads should not be measured, however, near the inlet baffle or in the downstream corner of a narrow tank.

**Table A.1 — Discharge coefficients for 90° V-notches and rectangular notches in small weir tanks**

| **Tank size** (length, width, height) | $C$ **values for 90° V-notches** [a] | | | $C_d$ **values for rectangular notches** [b] | | |
|---|---|---|---|---|---|---|
| | **Head** ($h$) mm | | | **Head** ($h$) mm | | |
| m | **115** | **150** | **180** | **65** | **100** | **135** |
| 2,62 × 0,92 × 0,45 | 0,593 | 0,592 | 0,587 | 0,609 | 0,592 | 0,588 |
| 1,50 × 0,92 × 0,45 | 0,603 | 0,592 | 0,587 | 0,604 | 0,592 | 0,588 |
| 1,00 × 0,92 × 0,45 | 0,603 | 0,592 | 0,587 | 0,600 | 0,590 | 0,588 |
| 2,62 × 0,75 × 0,45 | 0,597 | 0,592 | 0,590 | 0,606 | 0,593 | 0,588 |
| 2,62 × 0,50 × 0,45 | 0,605 | 0,596 | 0,595 | 0,611 | 0,598 | 0,598 |
| 2,62 × 0,92 × 0,30 | 0,600 | 0,590 | 0,586 | 0,606 | 0,592 | 0,588 |
| 2,62 × 0,92 × 0,15 | 0,602 | 0,597 | 0,593 | 0,613 | 0,598 | 0,595 |

a $Q = C\frac{8}{15}\sqrt{2g}\, h^{5/2}$

b $Q = C\frac{2}{3}\sqrt{2g}\, b_e\, h_e^{3/2}$

2) Available from Hydraulics Research Ltd., Wallingford, Oxon., England, as Report No. EX1243, 1985.



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**Table A.2 — Discharge coefficients for rectangular notches in small weir tanks with sediment deposits**

| **Tank size** (length, width, height) | **Max. level of deposits relative to weir crest** | $C_d$ **values for rectangular notches** [a] | | |
|---|---|---|---|---|
| | | **Head** ($h$) mm | | |
| m | mm | **65** | **100** | **135** |
| 2,62 × 0,92 × 0,45 | − 150 | 0,605 | 0,591 | 0,588 |
| | − 40 | 0,606 | 0,597 | 0,590 |
| | − 40 (+ 100 at sides) | 0,613 | 0,601 | 0,595 |

[a] $Q = C \frac{2}{3} \sqrt{2g}\, b_e\, h_e^{3/2}$



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# Annex B
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## Guide to the design and installation of a flow straightener

A flow straightener may be used for reducing the approach channel length.

The purpose of a flow straightener is to modify the flow in a shortened approach channel so that the velocity distribution of the flow is normal and steady.

Subclause 6.3.3 and Figure 1 specify a normal velocity distribution.

A flow straightener should consist of several perforated plates (at least four), installed vertically and perpendicular to the flow direction with a minimum spacing of 0,2 m between adjacent plates. The percentage of the open area of each plate should be between 40 % and 60 % inclusive.

Figure B.1 shows an example of perforation. Holes are distributed in a staggered formation; in the example, the distance between the centres of two neighbouring holes is 30 mm; the hole diameter is 20 mm. This gives a percentage of open area equal to 40,31 %.

The plates should be thick and sufficiently strong to sustain the force exerted by the channel flow. The dimension of the holes may be varied in accordance with the channel width, provided that the spacing between the plates is adjusted in proportion to the hole diameter.

The straightener plates may be fixed on the approach channel, either with the perforations of the different plates aligned on the general direction of the stream (Figure B.2), or with them positioned in a staggered formation, provided that the distance between adjacent plates is large compared with the hole diameter (Figure B.3).

Dimensions in millimetres

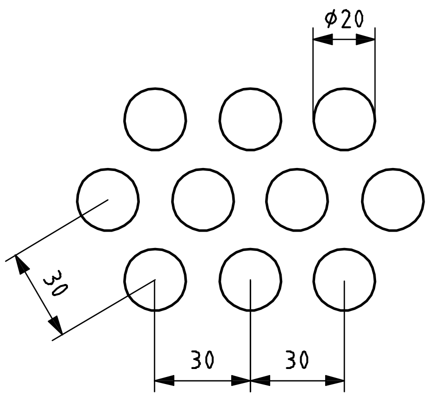


**Figure B.1 — Example of perforation**

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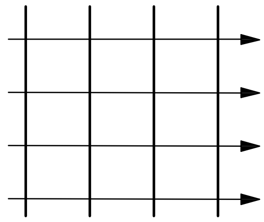

Figure B.2 — Aligned perforations

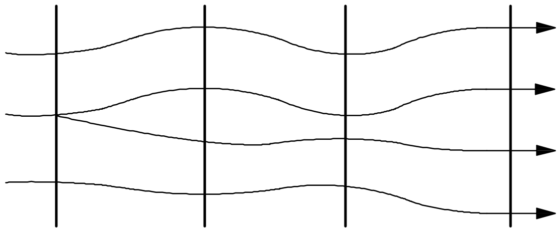

Figure B.3 — Staggered perforations


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# Annex C
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# Introduction to measurement uncertainty

## C.1 General

Results of measurements or analysis cannot be exact. The discrepancy between the true value, which is unknowable, and the measured value is the measurement error. The concept of uncertainty is a way of expressing this lack of knowledge. For example, if water is controlled to flow at a constant rate, then a flow meter will exhibit a spread of measurements about a mean value. If attention is not given to the uncertain nature of data, incorrect decisions can be made which have financial or judicial consequences. A realistic statement of uncertainty enhances the quality of information, making it more useful.

The uncertainty of a measurement represents a dispersion of values that could be attributed to it. Statistical methods provide objective values based on the application of theory.

Standard uncertainty is defined as:

*Standard uncertainty equates to a dispersion of measurements expressed as a standard deviation.*

From this definition, uncertainty can be readily calculated for a set of set of measurements.


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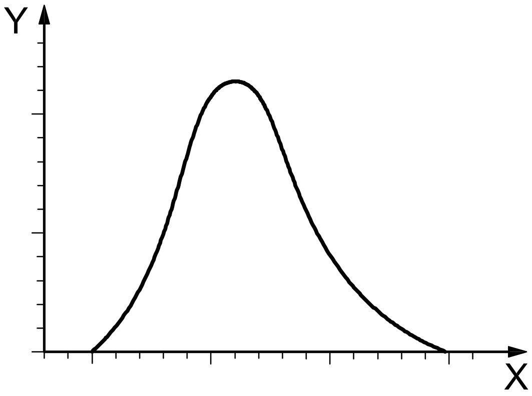
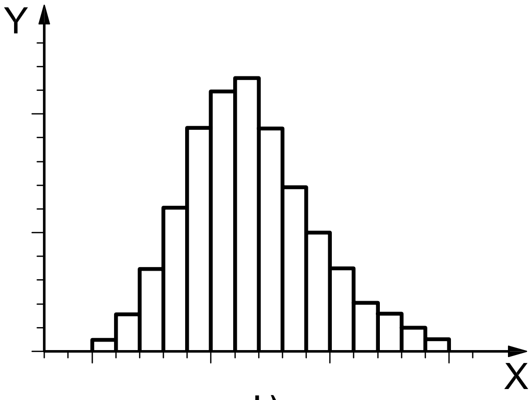



a)

**Key**

X flow value

Y probability

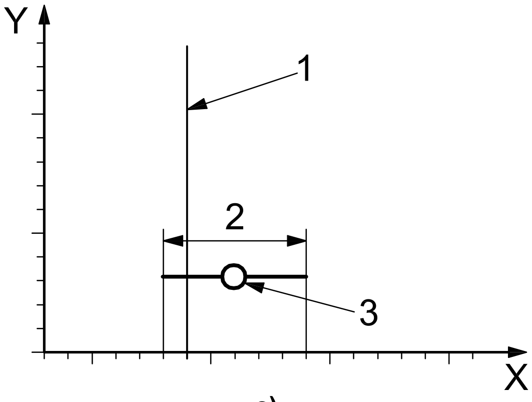



b)

**Key**

X flow value

Y number of samples




c)

**Key**

1 limit

2 standard deviation

3 mean value

X flow value

Y number of samples

**Figure C.1 — Pictorial representation of some uncertainty paramaters**

--`,,```,,,,````-`-`,,`,,`,`,,`---



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Figure C.1 a) shows the probability that a measurement of flow under steady conditions takes a particular value due to the uncertainties of various components of the measurement process, in the form of a probability density function.

Figure C.1 b) shows sampled flow measurements, in the form of a histogram.

Figure C.1 c) shows standard deviation of the sampled measurements compared with a limiting value. The mean value is shown to exceed the limiting value but is within the band of uncertainty (expressed as the standard deviation about the mean value).

## C.2 Confidence limits and coverage factors

For a normal probability distribution, analysis shows that 68 % of a large set of measurements lies within one standard deviation of the mean value. Thus, standard uncertainty is said to have a 68 % level of confidence.

However, for some measurement results, it is customary to express the uncertainty at a level of confidence which will cover a larger portion of the measurements: for example at a 95 % level of confidence (see Figure C.4). This is done by applying a factor, the coverage factor $k$, to the computed value of standard uncertainty.

For a normal probability distribution, 95,45 % (effectively 95 %) of the measurements are covered for a value of $k = 2$. Thus, uncertainty at the 95 % level of confidence is twice the standard uncertainty value.

In practice, measurement variances rarely follow closely the normal probability distribution. They may be better represented by triangular, rectangular or bimodal probability distributions and only sometimes approximate to the normal distribution.

So a probability distribution must be selected to model the observed variances. To express the uncertainty of such models at the 95 % confidence limit requires a coverage factor that represents 95 % of the observations. However, the same coverage factor, $k = 2$, is used for all models. This simplifies the procedure while ensuring consistency of application within tolerable limits.

## C.3 Random and systematic error

The terms “random” and “systematic” have been applied in hydrometric standards to distinguish between i) random error that represent an inherent dispersion of values under steady conditions, and ii) systematic errors that are associated with inherent limitations of the means of determining the measured quantity.

A difficulty with the concept of systematic error is that systematic error cannot be determined without pre-knowledge of true values. If its existence is known or suspected, then steps must be taken to minimize such error either by recalibration of equipment or by reversing its effect in the calculation procedure. At which point, systematic error contributes to uncertainty in the same way as random components of uncertainty.

For this reason, the GUM does not distinguish between the treatment of random and systematic uncertainties. Generally, when determining a single discharge, random errors dominate and there is no need to separate random and systematic errors. However, where (say) totalized volume is established over a long time base, the systematic errors, even when reduced, can remain dominant in the estimation of uncertainty.

## C.4 Measurement standards

The GUM and the HUG provide rules for the application of the principles of measurement uncertainty: in particular on the identification of components of error, the quantification of their corresponding uncertainties and how these are combined using methods derived from statistical theory into an overall result for the measurement process.

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The components of uncertainty are characterized by estimates of standard deviations. There are two methods of estimation:

a) **Type-A estimation** (by statistical analysis of repeated measurements from which an equivalent standard deviation is derived)

   This process may be automated in real-time for depth or for velocity measurement.

b) **Type-B estimation** (by ascribing a probability distribution to the measurement process)

   This is applicable to:

   1) human judgement of a manual measurement (distance or weight),

   2) manual readings taken from instrumentation (manufacturer's statement), or

   3) calibration data (from manufacturer).

## C.5 Evaluation of Type-A uncertainty

Defined in C.1, the term “standard uncertainty” equates to a dispersion of measurements expressed as a standard deviation. Thus, any single measurement of a set of $n$ measurements has by definition an uncertainty:

$$u(x) = t_{\mathrm{e}} \sqrt{\frac{1}{n-1} \sum_{i=1}^{n} \left(x_i - \bar{x}\right)^2} \quad \text{(C.1)}$$

where $\bar{x}$ is the best estimate of the true mean:

$$\bar{x} = \frac{1}{n}\left(x_1 + x_2 + .....x_n\right) \quad \text{(C.2)}$$

and $t_{\mathrm{e}}$ is a factor derived from statistical theory to account for the increased uncertainty when small numbers of measurements are available: refer to Table C.1.

If, instead of a single measurement from the set, the uncertainty is to apply to the mean of all $n$ values, then:

$$u(\bar{x}) = \frac{t_{\mathrm{e}}}{\sqrt{n}} \sqrt{\frac{1}{n-1} \sum_{i=1}^{n} \left(x_i - \bar{x}\right)^2} \quad \text{(C.3)}$$

For continuous measurement, Type-A evaluations may be derived as a continuous variable from the primary measurement, i.e. from water level or water velocity.

By taking average values over large numbers, $n$, of measurements, the uncertainty of the mean value $u(\bar{x})$ is reduced by a factor of $\frac{1}{\sqrt{n}}$ compared to the uncertainty $u(x)$ of an individual measurement. For this reason, monitoring equipment should specify measurement performance in terms including both $u(\bar{x})$ and $u(x)$ to show the extent to which averaging is applied.


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**Table C.1 — $t_e$ factors at 90 %, 95 % and 99 % confidence levels**

| Degrees of freedom [a] | Confidence level % | | |
|---|---|---|---|
| | 90 | 95 | 99 |
| 1 | 6,31 | 12,71 | 63,66 |
| 2 | 2,92 | 4,30 | 9,92 |
| 3 | 2,35 | 3,18 | 5,84 |
| 4 | 2,13 | 2,78 | 4,60 |
| 5 | 2,02 | 2,57 | 4,03 |
| 10 | 1,81 | 2,23 | 3,17 |
| 15 | 1,75 | 2,13 | 2,95 |
| 20 | 1,72 | 2,09 | 2,85 |
| 25 | 1,71 | 2,06 | 2,79 |
| 30 | 1,70 | 2,04 | 2,75 |
| 40 | 1,68 | 2,02 | 2,70 |
| 60 | 1,67 | 2,00 | 2,66 |
| 100 | 1,66 | 1,98 | 2,63 |
| Infinite | 1,64 | 1,96 | 2,58 |

[a] In general, the number of terms in a sum minus the number of constraints on the terms of the sum (GUM).

## C.6 Evaluation of Type-B uncertainty

### C.6.1 General

When there is no access to a continuous stream of measured data or if a large set of measurements is not available, then the type-B method of estimation is used to:

i) assign a probability distribution to the measurement process to represent the probability of the true value being represented by any single measured value;

ii) define upper and lower bounds of the measurement; and then

iii) determine a standard uncertainty from a standard deviation implied by the assigned probability distribution.

The Type-B methods allow estimates of upper and lower bounding values to be used to derive the equivalent standard deviation.

Four probability distributions are described in the GUM and in C.6.2 to C.6.5.

### C.6.2 The triangular distribution

The triangular distribution is represented in Figure C.2.

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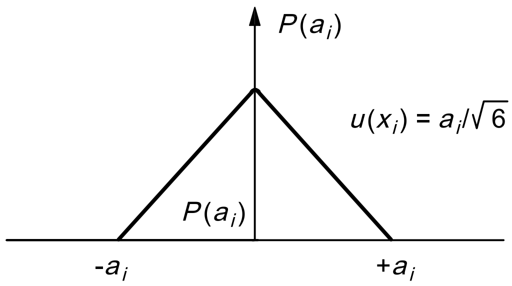


**Figure C.2 — The triangular distribution**

$$u\left(x_{\text{mean}}\right) = \frac{1}{\sqrt{6}}\left(\frac{x_{\text{max}} - x_{\text{min}}}{2}\right) \tag{C.4}$$

This usually applies to manual measurements where the mean value is most likely to be closer to the true value than others between the discernible upper and lower limits of the measurement.

### C.6.3 The rectangular distribution

The rectangular distribution is represented in Figure C.3.

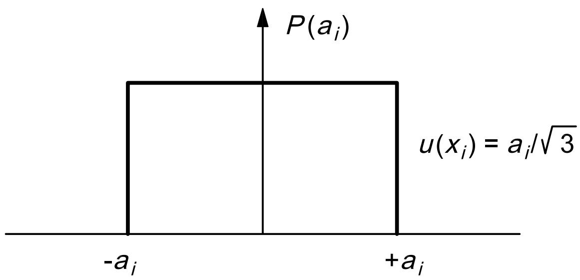


**Figure C.3 — The rectangular distribution**

$$u\left(x_{\text{mean}}\right) = \frac{1}{\sqrt{3}}\left(\frac{x_{\text{max}} - x_{\text{min}}}{2}\right) \tag{C.5}$$

This probability distribution is usually applied to the resolution limit of the measurement instrumentation (i.e. the displayed resolution or the resolution of internal analogue/digital converters).

However, this is not the only source of uncertainty of measurement equipment. There may be uncertainty arising from the measurement algorithm used and/or from the calibration process.

If the equipment measures relative values, then there will also be uncertainty in the determination of its datum.

### C.6.4 The normal probability distribution

The normal probability distribution is represented in Figure C.4.


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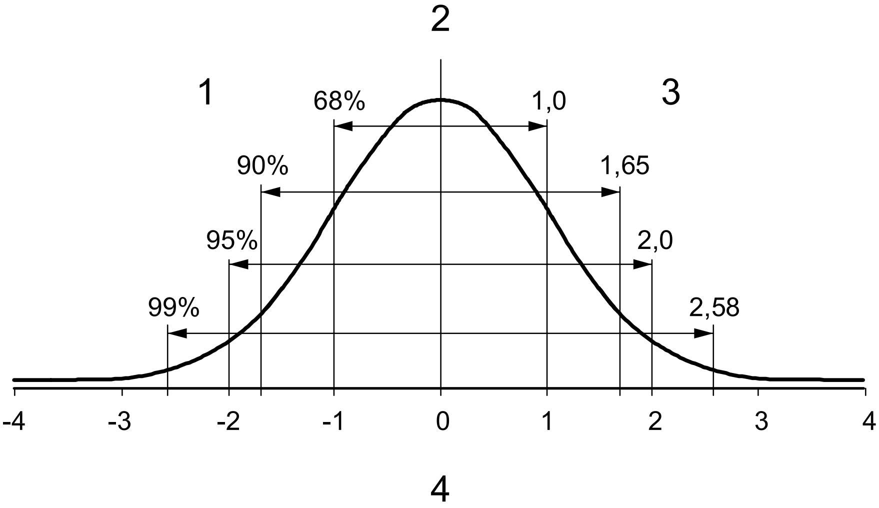


**Key**

1 percent of readings in bandwidth

2 probability

3 coverage factor

4 standard deviations

**Figure C.4 — The normal probability distribution**

$$u(x_{\text{mean}}) = \frac{u(\text{specified})}{k} \qquad \text{(C.6.)}$$

where $k$ is the coverage factor applying to the specified uncertainty value.

These are uncertainty statements based on "off-line" statistical analysis, usually as part of a calibration process where they have been derived using a Type-A process. When expressed as standard uncertainty, the uncertainty value is to be used directly with an equivalent coverage factor of $k = 1$.

## C.6.5 The bimodal probability distribution

The bimodal probability distribution is represented in Figure C.5.

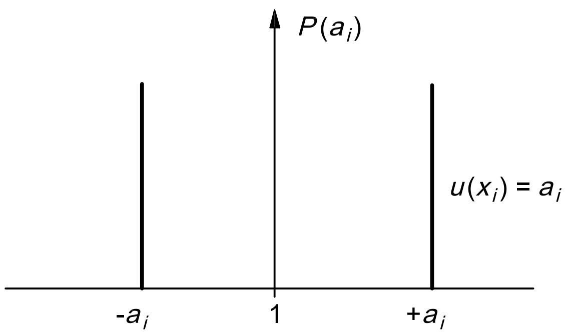


**Figure C.5 — The bimodal probability distribution**

$$u(x_{\text{mean}}) = \frac{(x_{\text{max}} - x_{\text{min}})}{2} \qquad \text{(C.7)}$$


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Measurement equipment with hystersis can only exhibit values at the upper and lower bounds of the measurement.

An example of this is the float mechanism where friction and surface tension combine to cause the float to move in finite steps.

## C.7 Combined uncertainty value, $u_c$

For most measurement systems, a measurement result is derived from several variables. For example, flow measurement, $Q$, in a rectangular channel can be expressed as a function of independent variables:

$$Q = b \times h \times \bar{V} \quad \text{(C.8)}$$

where

$b$ is the channel width;

$h$ is the depth of water in the channel;

$\bar{V}$ is the mean velocity.

These three components are measured independently and combined to determine a value for $Q$.

Just as $b$, $h$ and $\bar{V}$ are combined to determine the value $Q$, so each component of uncertainty must be combined to determine a value for $u_c(Q)$. This is done by evaluating the sensitivity of $Q$ to small change, $\Delta$, in $b$, $h$ or $V$. Thus:

$$\Delta Q = \frac{\partial Q}{\partial b}\Delta b + \frac{\partial Q}{\partial h}\Delta h + \frac{\partial Q}{\partial \bar{V}}\Delta \bar{V} \quad \text{(C.9)}$$

where the partial differentials, $\frac{\partial Q}{\partial b}$, $\frac{\partial Q}{\partial h}$ and $\frac{\partial Q}{\partial \bar{V}}$ are sensitivity coefficients. For the equation $Q = b \times h \times \bar{V}$, this is equal to:

$$\frac{\Delta Q}{Q} = \frac{\Delta b}{b} + \frac{\Delta h}{h} + \frac{\Delta \bar{V}}{\bar{V}} \quad \text{(C.10)}$$

In uncertainty analysis, the values $\frac{\Delta Q}{Q}$, $\frac{\Delta b}{b}$, $\frac{\Delta h}{h}$ and $\frac{\Delta \bar{V}}{\bar{V}}$ correspond to dimensionless standard uncertainties. They are given the notation $u_c^*(Q)$, $u^*(b)$, $u^*(h)$ and $u^*(V)$.

Since the uncertainties of $b$, $V$ and $h$ are independent of each other, probability considerations require summation in quadrature.

$$u_c^*(Q) \cong \sqrt{u^*(\bar{V})^2 + u^*(b)^2 + u^*(h)^2} \quad \text{(C.11)}$$


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# Annex D
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# Sample measurement performance for use in hydrometric worked examples

**Table D.1 — Sample measurement performance for use in hydrometric worked examples**



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| Measurement technologies | | Comment | Symbol | Uncertainty Options | | Installed equipment to have corresponding values certified by the manufacturer | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Nominal range of measurement | | | | | Corresponding standard uncertainty (68 % confidence limit) | | | | |
| **Velocity (continuous)** | | | | A | B | Minimum | 25 % | 50 % | 75 % | Maximum | Minimum | 25 % | 50 % | 75 % | Maximum |
| Point Velocity | Propeller | Calibration certificate | $u(V)$ | YES | Normal | 0,005 m/s | 1,250 m/s | 2,500 m/s | 3,750 m/s | 5,000 m/s | 0,000 5 m/s | 0,010 m/s | 0,022 m/s | 0,030 m/s | 0,040 m/s |
| | Electromagnetic | Calibration certificate | $u(V)$ | YES | Normal | 0,005 m/s | 0,750 m/s | 1,500 /s | 2,250 m/s | 3,000 m/s | 0,000 5 m/s | 0,010 m/s | 0,018 m/s | 0,025 m/s | 0,025 m/s |
| Path velocity | Time of flight sonar | Sonic velocity path angle | $u(V)$ | YES | Rectangular | 0,030 m/s | 0,250 m/s | 0,500 m/s | 0,750 m/s | 1,000 m/s | 0,003 m/s | 0,005 m/s | 0,007 m/s | 0,007 m/s | 0,010 m/s |
| | Gated Doppler sonar | Particle dependent - low velocity resolution | $u(V)$ | YES | Rectangular | 0,030 m/s | 0,250 m/s | 0,500 m/s | 0,750 m/s | 1,000 m/s | 0,003 m/s | 0,005 m/s | 0,007 m/s | 0,007 m/s | 0,010 m/s |
| | Sonar correlation | Particle dependent | $u(V)$ | YES | Rectangular | 0,030 m/s | 0,250 m/s | 0,500 m/s | 0,750 m/s | 1,000 m/s | 0,003 m/s | 0,005 m/s | 0,007 m/s | 0,007 m/s | 0,010 m/s |
| Section Velocity | EM | To be calibrated *in situ* | $u(V)$ | | Rectangular | 0,030 m/s | 0,250 m/s | 0,500 m/s | 0,750 m/s | 1,000 m/s | 0,003 m/s | 0,005 m/s | 0,007 m/s | 0,007 m/s | 0,010 m/s |
| **Water level (continuous)** | | | | | | | | | | | | | | | |
| Relative Datum (must be applied to all methods) | | Manual process | $u(E)$ | | Triangular | Not applicable | 0,500 m | 1,000 m | 1,500 m | 2,000 m | 0,001 m | 0,001 m | 0,001 5 m | 0,001 5 m | 0,001 5 m |
| In-contact methods | Encoder/float system | Requires regular maintenance | $u(h_1)$ | | Bimodal | Extension 0,200 m | Extension 1,250 m | Extension 2,500 m | Extension 3,750 m | Extension 5,000 m | 0,001 5 m | 0,002 0 m | 0,002 0 m | 0,002 5 m | 0,002 5 m |
| | Pressure transducer | Datum value drift | $u(h_1)$ | | Rectangular | 0,010 m | 0,500 m | 1,000 m | 1,500 m | 2,000 m | 0,002 m | 0,002 m | 0,002 5 m | 0,002 5 m | 0,003 0 m |
| | Sonar | Surface wave effects | $u(h_1)$ | YES | Rectangular | 0,050 m | 0,500 m | 1,000 m | 1,500 m | 2,000 m | 0,001 m | 0,001 m | 0,001 5 m | 0,001 5 m | 0,001 5 m |
| Non-contact methods | Pulse echo ultrasound | Surface wave effects Air temperature Compensation | $u(R)$ | YES | Rectangular | Range 0,300 m | Range 1,250 m | Range 2,500 m | Range 3,750 m | Range 5,000 m | 0,002 m | 0,004 m | 0,010 m | 0,025 m | 0,060 m |
| | Pulse echo opto/radar | Surface wave effects | $u(R)$ | | Rectangular | Range 0,300 m | Range 1,250 m | Range 2,500 m | Range 3,750 m | Range 5,000 m | 0,002 m | 0,004 m | 0,010 m | 0,025 m | 0,060 m |
| **Cross-section profile (distance measurement)** | | | | | | | | | | | | | | | |
| | Natural channels | Sonar or dip gauging/GPRS or tracking | $u(B)$ | | Rectangular | 0,500 m | 5,000 m | 10,000 m | 15,000 m | 20,000 m | 0,002 m | 0,020 m | 0,060 m | 0,100 m | 0,200 m |
| | Man-made channels | Manual measurement | $u(B)$ | | Triangular | Not applicable | 0,500 m | 1,000 m | 1,500 m | 2,000 m | 0,001 m | 0,001 m | 0,0015 m | 0,0015 m | 0,0015 m |

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# Annex E
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# Specimen tables

**Table E.1 — Discharge of water over a V-notch with tan $\frac{\alpha}{2} = 1$ ($\alpha = \frac{\pi}{2}$ radians or 90°)**

$$Q = 2{,}362\ 5\ C_d h^{5/2}$$

($g = 9{,}806\ 6$ m/s$^2$)

| Head<br>$h$<br>m | Coefficient<br>$C_d$ | Discharge<br>$Q$<br>m$^3$/s × 10$^{-1}$ | Head<br>$h$<br>m | Coefficient<br>$C_d$ | Discharge<br>$Q$<br>m$^3$/s × 10$^{-1}$ |
|---|---|---|---|---|---|
| 0,060 | 0,603 2 | 0,012 57 | 0,085 | 0,595 0 | 0,029 61 |
| 0,061 | 0,602 8 | 0,013 09 | 0,086 | 0,594 8 | 0,030 48 |
| 0,062 | 0,602 3 | 0,013 62 | 0,087 | 0,594 5 | 0,031 36 |
| 0,063 | 0,601 9 | 0,014 17 | 0,088 | 0,594 2 | 0,032 25 |
| 0,064 | 0,601 5 | 0,014 73 | 0,089 | 0,594 0 | 0,033 16 |
| 0,065 | 0,601 2 | 0,015 30 | | | |
| 0,066 | 0,600 8 | 0,015 88 | 0,090 | 0,593 7 | 0,034 09 |
| 0,067 | 0,600 5 | 0,016 48 | 0,091 | 0,593 5 | 0,035 03 |
| 0,068 | 0,600 1 | 0,017 10 | 0,092 | 0,593 3 | 0,035 98 |
| 0,069 | 0,599 8 | 0,017 72 | 0,093 | 0,593 1 | 0,036 96 |
| | | | 0,094 | 0,592 9 | 0,037 95 |
| 0,070 | 0,599 4 | 0,018 36 | 0,095 | 0,592 7 | 0,038 95 |
| 0,071 | 0,599 0 | 0,019 01 | 0,096 | 0,592 5 | 0,039 97 |
| 0,072 | 0,598 7 | 0,019 67 | 0,097 | 0,592 3 | 0,041 01 |
| 0,073 | 0,598 3 | 0,020 35 | 0,098 | 0,592 1 | 0,042 06 |
| 0,074 | 0,598 0 | 0,021 05 | 0,099 | 0,591 9 | 0,043 12 |
| 0,075 | 0,597 8 | 0,021 76 | | | |
| 0,076 | 0,597 5 | 0,022 48 | 0,100 | 0,591 7 | 0,044 20 |
| 0,077 | 0,597 3 | 0,023 22 | 0,101 | 0,591 4 | 0,045 30 |
| 0,078 | 0,597 0 | 0,023 97 | 0,102 | 0,591 2 | 0,046 41 |
| 0,079 | 0,596 7 | 0,024 73 | 0,103 | 0,591 0 | 0,047 54 |
| | | | 0,104 | 0,590 8 | 0,048 69 |
| 0,080 | 0,596 4 | 0,025 51 | 0,105 | 0,590 6 | 0,049 85 |
| 0,081 | 0,596 1 | 0,026 30 | 0,106 | 0,590 4 | 0,051 03 |
| 0,082 | 0,595 8 | 0,027 10 | 0,107 | 0,590 2 | 0,052 22 |
| 0,083 | 0,595 5 | 0,027 92 | 0,108 | 0,590 1 | 0,053 44 |
| 0,084 | 0,595 3 | 0,028 76 | 0,109 | 0,589 9 | 0,054 67 |

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**Table E.1** (*continued*)

| Head $h$ m | Coefficient $C_d$ | Discharge $Q$ m³/s × 10⁻¹ | Head $h$ m | Coefficient $C_d$ | Discharge $Q$ m³/s × 10⁻¹ |
|---|---|---|---|---|---|
| 0,110 | 0,589 8 | 0,055 92 | 0,144 | 0,586 6 | 0,109 04 |
| 0,111 | 0,589 7 | 0,057 19 | 0,145 | 0,586 5 | 0,110 93 |
| 0,112 | 0,589 6 | 0,058 47 | 0,146 | 0,586 4 | 0,112 84 |
| 0,113 | 0,589 4 | 0,059 77 | 0,147 | 0,586 3 | 0,114 76 |
| 0,114 | 0,589 2 | 0,061 08 | 0,148 | 0,586 2 | 0,116 71 |
| 0,115 | 0,589 1 | 0,062 42 | 0,149 | 0,586 2 | 0,118 67 |
| 0,116 | 0,589 0 | 0,063 77 | | | |
| 0,117 | 0,588 9 | 0,065 14 | 0,150 | 0,586 1 | 0,120 66 |
| 0,118 | 0,588 8 | 0,066 53 | 0,151 | 0,586 1 | 0,122 67 |
| 0,119 | 0,588 6 | 0,067 93 | 0,152 | 0,586 0 | 0,124 71 |
| | | | 0,153 | 0,586 0 | 0,126 76 |
| 0,120 | 0,588 5 | 0,069 35 | 0,154 | 0,585 9 | 0,128 83 |
| 0,121 | 0,588 3 | 0,070 79 | 0,155 | 0,585 9 | 0,130 93 |
| 0,122 | 0,588 2 | 0,072 24 | 0,156 | 0,585 9 | 0,133 04 |
| 0,123 | 0,588 1 | 0,073 72 | 0,157 | 0,585 8 | 0,135 17 |
| 0,124 | 0,588 0 | 0,075 22 | 0,158 | 0,585 8 | 0,137 32 |
| 0,125 | 0,588 0 | 0,076 73 | 0,159 | 0,585 7 | 0,139 50 |
| 0,126 | 0,587 9 | 0,078 27 | | | |
| 0,127 | 0,587 8 | 0,079 82 | 0,160 | 0,585 7 | 0,141 69 |
| 0,128 | 0,587 7 | 0,081 39 | 0,161 | 0,585 7 | 0,143 91 |
| 0,129 | 0,587 6 | 0,082 98 | 0,162 | 0,585 6 | 0,146 14 |
| | | | 0,163 | 0,585 6 | 0,148 40 |
| 0,130 | 0,587 6 | 0,084 58 | 0,164 | 0,585 5 | 0,150 67 |
| 0,131 | 0,587 5 | 0,086 21 | 0,165 | 0,585 5 | 0,152 97 |
| 0,132 | 0,587 4 | 0,087 85 | 0,166 | 0,585 5 | 0,155 29 |
| 0,133 | 0,587 3 | 0,089 51 | 0,167 | 0,585 4 | 0,157 63 |
| 0,134 | 0,587 2 | 0,091 19 | 0,168 | 0,585 4 | 0,159 99 |
| 0,135 | 0,587 2 | 0,092 89 | 0,169 | 0,585 3 | 0,162 37 |
| 0,136 | 0,587 1 | 0,094 61 | | | |
| 0,137 | 0,587 0 | 0,096 34 | 0,170 | 0,585 3 | 0,164 77 |
| 0,138 | 0,586 9 | 0,098 10 | 0,171 | 0,585 3 | 0,167 19 |
| 0,139 | 0,586 9 | 0,099 87 | 0,172 | 0,585 2 | 0,169 64 |
| | | | 0,173 | 0,585 2 | 0,172 10 |
| 0,140 | 0,586 8 | 0,101 67 | 0,174 | 0,585 1 | 0,174 59 |
| 0,141 | 0,586 7 | 0,103 48 | 0,175 | 0,585 1 | 0,177 09 |
| 0,142 | 0,586 7 | 0,105 32 | 0,176 | 0,585 1 | 0,179 63 |
| 0,143 | 0,586 6 | 0,107 17 | 0,177 | 0,585 1 | 0,182 19 |


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**Table E.1** (*continued*)

| Head<br>$h$<br>m | Coefficient<br>$C_d$ | Discharge<br>$Q$<br>$m^3/s \times 10^{-1}$ |
|---|---|---|
| 0,178 | 0,585 1 | 0,184 78 |
| 0,179 | 0,585 1 | 0,187 38 |
| 0,180 | 0,585 1 | 0,190 01 |
| 0,181 | 0,585 1 | 0,192 65 |
| 0,182 | 0,585 0 | 0,195 31 |
| 0,183 | 0,585 0 | 0,198 00 |
| 0,184 | 0,585 0 | 0,200 71 |
| 0,185 | 0,585 0 | 0,203 45 |
| 0,186 | 0,585 0 | 0,206 21 |
| 0,187 | 0,585 0 | 0,208 99 |
| 0,188 | 0,585 0 | 0,211 80 |
| 0,189 | 0,585 0 | 0,214 63 |
| 0,190 | 0,585 0 | 0,217 48 |
| 0,191 | 0,585 0 | 0,220 34 |
| 0,192 | 0,584 9 | 0,223 22 |
| 0,193 | 0,584 9 | 0,226 12 |
| 0,194 | 0,584 9 | 0,229 06 |
| 0,195 | 0,584 9 | 0,232 03 |
| 0,196 | 0,584 9 | 0,235 01 |
| 0,197 | 0,584 9 | 0,238 02 |
| 0,198 | 0,584 9 | 0,241 06 |
| 0,199 | 0,584 9 | 0,244 11 |
| 0,200 | 0,584 9 | 0,247 19 |
| 0,201 | 0,584 9 | 0,250 28 |
| 0,202 | 0,584 8 | 0,253 39 |
| 0,203 | 0,584 8 | 0,256 52 |
| 0,204 | 0,584 8 | 0,259 69 |
| 0,205 | 0,584 8 | 0,262 88 |
| 0,206 | 0,584 8 | 0,266 10 |
| 0,207 | 0,584 8 | 0,269 34 |
| 0,208 | 0,584 8 | 0,272 61 |
| 0,209 | 0,584 8 | 0,275 90 |
| 0,210 | 0,584 8 | 0,279 21 |

| Head<br>$h$<br>m | Coefficient<br>$C_d$ | Discharge<br>$Q$<br>$m^3/s \times 10^{-1}$ |
|---|---|---|
| 0,211 | 0,584 8 | 0,282 54 |
| 0,212 | 0,584 8 | 0,285 88 |
| 0,213 | 0,584 7 | 0,289 24 |
| 0,214 | 0,584 7 | 0,292 64 |
| 0,215 | 0,584 7 | 0,296 07 |
| 0,216 | 0,584 7 | 0,299 53 |
| 0,217 | 0,584 7 | 0,303 01 |
| 0,218 | 0,584 7 | 0,306 51 |
| 0,219 | 0,584 7 | 0,310 04 |
| 0,220 | 0,584 7 | 0,313 59 |
| 0,221 | 0,584 7 | 0,317 17 |
| 0,222 | 0,584 7 | 0,320 77 |
| 0,223 | 0,584 7 | 0,324 39 |
| 0,224 | 0,584 7 | 0,328 03 |
| 0,225 | 0,584 6 | 0,331 68 |
| 0,226 | 0,584 6 | 0,335 35 |
| 0,227 | 0,584 6 | 0,339 07 |
| 0,228 | 0,584 6 | 0,342 82 |
| 0,229 | 0,584 6 | 0,346 59 |
| 0,230 | 0,584 6 | 0,350 39 |
| 0,231 | 0,584 6 | 0,354 21 |
| 0,232 | 0,584 6 | 0,358 06 |
| 0,233 | 0,584 6 | 0,361 93 |
| 0,234 | 0,584 6 | 0,365 82 |
| 0,235 | 0,584 6 | 0,369 74 |
| 0,236 | 0,584 6 | 0,373 69 |
| 0,237 | 0,584 6 | 0,377 66 |
| 0,238 | 0,584 6 | 0,381 66 |
| 0,239 | 0,584 6 | 0,385 68 |
| 0,240 | 0,584 6 | 0,389 73 |
| 0,241 | 0,584 6 | 0,393 80 |
| 0,242 | 0,584 6 | 0,397 90 |
| 0,243 | 0,584 6 | 0,402 02 |
| 0,244 | 0,584 6 | 0,406 17 |

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**Table E.1** (*continued*)

| **Head** $h$ m | **Coefficient** $C_d$ | **Discharge** $Q$ $m^3/s \times 10^{-1}$ |
|---|---|---|
| 0,245 | 0,584 6 | 0,410 34 |
| 0,246 | 0,584 6 | 0,414 54 |
| 0,247 | 0,584 6 | 0,418 77 |
| 0,248 | 0,584 6 | 0,423 02 |
| 0,249 | 0,584 6 | 0,427 30 |
| 0,250 | 0,584 6 | 0,431 60 |
| 0,251 | 0,584 6 | 0,435 93 |
| 0,252 | 0,584 6 | 0,440 28 |
| 0,253 | 0,584 6 | 0,440 66 |
| 0,254 | 0,584 6 | 0,449 07 |
| 0,255 | 0,584 6 | 0,453 50 |
| 0,256 | 0,584 6 | 0,457 96 |
| 0,257 | 0,584 6 | 0,462 45 |
| 0,258 | 0,584 6 | 0,466 96 |
| 0,259 | 0,584 6 | 0,471 50 |
| 0,260 | 0,584 6 | 0,476 06 |
| 0,261 | 0,584 6 | 0,480 65 |
| 0,262 | 0,584 6 | 0,485 27 |
| 0,263 | 0,584 6 | 0,489 91 |
| 0,264 | 0,584 6 | 0,494 58 |
| 0,265 | 0,584 6 | 0,499 28 |
| 0,266 | 0,584 6 | 0,404 00 |
| 0,267 | 0,584 6 | 0,508 76 |
| 0,268 | 0,584 6 | 0,513 53 |
| 0,269 | 0,584 6 | 0,518 34 |
| 0,270 | 0,584 6 | 0,523 17 |
| 0,271 | 0,584 6 | 0,528 02 |
| 0,272 | 0,584 6 | 0,532 91 |
| 0,273 | 0,584 6 | 0,537 82 |
| 0,274 | 0,584 6 | 0,542 76 |
| 0,275 | 0,584 6 | 0,547 72 |
| 0,276 | 0,584 6 | 0,552 72 |
| 0,277 | 0,584 6 | 0,557 74 |
| 0,278 | 0,584 6 | 0,562 82 |
| 0,279 | 0,584 7 | 0,567 94 |

| **Head** $h$ m | **Coefficient** $C_d$ | **Discharge** $Q$ $m^3/s \times 10^{-1}$ |
|---|---|---|
| 0,280 | 0,584 7 | 0,573 06 |
| 0,281 | 0,584 7 | 0,578 19 |
| 0,282 | 0,584 7 | 0,583 35 |
| 0,283 | 0,584 7 | 0,588 53 |
| 0,284 | 0,584 7 | 0,593 75 |
| 0,285 | 0,584 7 | 0,598 99 |
| 0,286 | 0,584 7 | 0,604 25 |
| 0,287 | 0,584 7 | 0,609 55 |
| 0,288 | 0,584 7 | 0,614 87 |
| 0,289 | 0,584 7 | 0,620 23 |
| 0,290 | 0,584 7 | 0,625 60 |
| 0,291 | 0,584 7 | 0,631 01 |
| 0,292 | 0,584 7 | 0,636 45 |
| 0,293 | 0,584 7 | 0,664 95 |
| 0,294 | 0,584 8 | 0,647 48 |
| 0,295 | 0,584 8 | 0,653 03 |
| 0,296 | 0,584 8 | 0,658 58 |
| 0,297 | 0,584 8 | 0,664 16 |
| 0,298 | 0,584 8 | 0,669 76 |
| 0,299 | 0,584 8 | 0,675 39 |
| 0,300 | 0,584 8 | 0,681 06 |
| 0,301 | 0,584 8 | 0,686 75 |
| 0,302 | 0,584 8 | 0,692 46 |
| 0,303 | 0,584 8 | 0,698 21` |
| 0,304 | 0,584 8 | 0,703 98 |
| 0,305 | 0,584 8 | 0,709 80 |
| 0,306 | 0,584 8 | 0,715 68 |
| 0,307 | 0,584 9 | 0,721 59 |
| 0,308 | 0,584 9 | 0,727 50 |
| 0,309 | 0,584 9 | 0,733 41 |
| 0,310 | 0,584 9 | 0,739 36 |
| 0,311 | 0,584 9 | 0,745 34 |
| 0,312 | 0,584 9 | 0,751 35 |
| 0,313 | 0,584 9 | 0,757 38 |
| 0,314 | 0,584 9 | 0,763 44 |

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**Table E.1** (*continued*)

| Head<br>$h$<br>m | Coefficient<br>$C_d$ | Discharge<br>$Q$<br>$m^3/s \times 10^{-1}$ |
|---|---|---|
| 0,315 | 0,584 9 | 0,769 54 |
| 0,316 | 0,584 9 | 0,775 66 |
| 0,317 | 0,584 9 | 0,781 81 |
| 0,318 | 0,584 9 | 0,788 02 |
| 0,319 | 0,585 0 | 0,794 28 |
| 0,320 | 0,585 0 | 0,800 57 |
| 0,321 | 0,585 0 | 0,806 85 |
| 0,322 | 0,585 0 | 0,813 14 |
| 0,323 | 0,585 0 | 0,819 47 |
| 0,324 | 0,585 0 | 0,825 83 |
| 0,325 | 0,585 0 | 0,832 22 |
| 0,326 | 0,585 0 | 0,838 63 |
| 0,327 | 0,585 0 | 0,845 08 |
| 0,328 | 0,585 0 | 0,851 55 |
| 0,329 | 0,585 0 | 0,858 06 |
| 0,330 | 0,585 0 | 0,864 59 |
| 0,331 | 0,585 0 | 0,871 16 |
| 0,332 | 0,585 0 | 0,877 75 |
| 0,333 | 0,585 0 | 0,884 38 |
| 0,334 | 0,585 0 | 0,891 03 |
| 0,335 | 0,585 0 | 0,897 72 |
| 0,336 | 0,585 0 | 0,904 48 |
| 0,337 | 0,585 1 | 0,911 28 |
| 0,338 | 0,585 1 | 0,918 11 |
| 0,339 | 0,585 1 | 0,924 91 |
| 0,340 | 0,585 1 | 0,931 75 |
| 0,341 | 0,585 1 | 0,938 62 |
| 0,342 | 0,585 1 | 0,945 51 |
| 0,343 | 0,585 1 | 0,952 44 |
| 0,344 | 0,585 1 | 0,959 40 |
| 0,345 | 0,585 1 | 0,966 38 |
| 0,346 | 0,585 1 | 0,973 40 |
| 0,347 | 0,585 1 | 0,980 45 |
| 0,348 | 0,585 1 | 0,987 53 |
| 0,349 | 0,585 1 | 0,994 71 |

| Head<br>$h$<br>m | Coefficient<br>$C_d$ | Discharge<br>$Q$<br>$m^3/s \times 10^{-1}$ |
|---|---|---|
| 0,350 | 0,585 2 | 1,001 92 |
| 0,351 | 0,585 2 | 1,009 12 |
| 0,352 | 0,585 2 | 1,016 33 |
| 0,353 | 0,585 2 | 1,023 56 |
| 0,354 | 0,585 2 | 1,030 82 |
| 0,355 | 0,585 2 | 1,038 12 |
| 0,356 | 0,585 2 | 1,045 45 |
| 0,357 | 0,585 2 | 1,052 80 |
| 0,358 | 0,585 2 | 1,060 19 |
| 0,359 | 0,585 2 | 1,067 67 |
| 0,360 | 0,585 3 | 1,075 19 |
| 0,361 | 0,585 3 | 1,082 73 |
| 0,362 | 0,585 3 | 1,090 24 |
| 0,363 | 0,585 3 | 1,097 78 |
| 0,364 | 0,585 3 | 1,105 36 |
| 0,365 | 0,585 3 | 1,112 97 |
| 0,366 | 0,585 3 | 1,120 63 |
| 0,367 | 0,585 3 | 1,128 37 |
| 0,368 | 0,585 4 | 1,136 15 |
| 0,369 | 0,585 4 | 1,143 91 |
| 0,370 | 0,585 4 | 1,151 67 |
| 0,371 | 0,585 4 | 1,159 47 |
| 0,372 | 0,585 4 | 1,167 30 |
| 0,373 | 0,585 4 | 1,175 16 |
| 0,374 | 0,585 4 | 1,183 10 |
| 0,375 | 0,585 5 | 1,191 11 |
| 0,376 | 0,585 5 | 1,199 14 |
| 0,377 | 0,585 5 | 1,207 12 |
| 0,378 | 0,585 5 | 1,215 15 |
| 0,379 | 0,585 5 | 1,223 20 |
| 0,380 | 0,585 5 | 1,231 28 |
| 0,381 | 0,585 5 | 1,239 40 |

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**Table E.2 — Discharge of water over a V-notch with** tan $\frac{\alpha}{2}$ = 1/2 ($\alpha$ = 0,927 3 radians or 53° 8′)

$$Q = 1{,}181\ 25\ C_d h^{5/2}$$

($g$ = 9,806 6 m/s²)

| Head $h$ m | Coefficient $C_d$ | Discharge $Q$ m³/s × 10⁻¹ | Head $h$ m | Coefficient $C_d$ | Discharge $Q$ m³/s × 10⁻¹ |
|---|---|---|---|---|---|
| 0,060 | 0,611 4 | 0,006 37 | 0,088 | 0,604 4 | 0,016 40 |
| 0,061 | 0,611 1 | 0,006 63 | 0,089 | 0,604 2 | 0,016 86 |
| 0,062 | 0,610 8 | 0,006 91 | | | |
| 0,063 | 0,610 6 | 0,007 18 | 0,090 | 0,604 0 | 0,017 34 |
| 0,064 | 0,610 1 | 0,007 47 | 0,091 | 0,603 8 | 0,017 82 |
| 0,065 | 0,609 8 | 0,007 76 | 0,092 | 0,603 6 | 0,018 30 |
| 0,066 | 0,609 5 | 0,008 06 | 0,093 | 0,603 4 | 0,018 80 |
| 0,067 | 0,609 2 | 0,008 36 | 0,094 | 0,603 2 | 0,019 30 |
| 0,068 | 0,609 0 | 0,008 67 | 0,095 | 0,603 0 | 0,019 81 |
| 0,069 | 0,608 7 | 0,008 99 | 0,096 | 0,602 8 | 0,020 33 |
| | | | 0,097 | 0,602 6 | 0,020 86 |
| 0,070 | 0,608 4 | 0,009 32 | 0,098 | 0,602 4 | 0,021 39 |
| 0,071 | 0,608 1 | 0,009 65 | 0,099 | 0,602 2 | 0,021 94 |
| 0,072 | 0,607 9 | 0,009 99 | | | |
| 0,073 | 0,607 6 | 0,010 33 | 0,100 | 0,602 1 | 0,022 49 |
| 0,074 | 0,607 3 | 0,010 69 | 0,101 | 0,601 9 | 0,023 05 |
| 0,075 | 0,607 1 | 0,011 05 | 0,102 | 0,601 7 | 0,023 62 |
| 0,076 | 0,606 8 | 0,011 41 | 0,103 | 0,601 6 | 0,024 20 |
| 0,077 | 0,606 6 | 0,011 79 | 0,104 | 0,601 4 | 0,024 78 |
| 0,078 | 0,606 4 | 0,012 17 | 0,105 | 0,601 3 | 0,025 37 |
| 0,079 | 0,606 1 | 0,012 56 | 0,106 | 0,600 9 | 0,026 59 |
| | | | 0,107 | 0,600 8 | 0,027 20 |
| 0,080 | 0,606 0 | 0,012 96 | 0,108 | 0,600 6 | 0,027 83 |
| 0,081 | 0,605 8 | 0,013 36 | 0,109 | | |
| 0,082 | 0,605 6 | 0,013 77 | | | |
| 0,083 | 0,605 4 | 0,014 19 | 0,110 | 0,600 5 | 0,028 47 |
| 0,084 | 0,605 2 | 0,014 62 | 0,111 | 0,600 3 | 0,029 11 |
| 0,085 | 0,605 0 | 0,015 05 | 0,112 | 0,600 2 | 0,029 76 |
| 0,086 | 0,604 8 | 0,015 49 | 0,113 | 0,600 0 | 0,030 42 |
| 0,087 | 0,604 6 | 0,015 94 | 0,114 | 0,599 8 | 0,031 09 |


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**Table E.2** (*continued*)

| Head<br>$h$<br>m | Coefficient<br>$C_d$ | Discharge<br>$Q$<br>$m^3/s \times 10^{-1}$ |
|---|---|---|
| 0,115 | 0,599 7 | 0,031 77 |
| 0,116 | 0,599 5 | 0,032 46 |
| 0,117 | 0,599 4 | 0,033 15 |
| 0,118 | 0,599 2 | 0,033 86 |
| 0,119 | 0,599 1 | 0,034 57 |
| 0,120 | 0,598 9 | 0,035 29 |
| 0,121 | 0,598 8 | 0,036 02 |
| 0,122 | 0,598 7 | 0,036 77 |
| 0,123 | 0,598 5 | 0,037 51 |
| 0,124 | 0,598 4 | 0,038 27 |
| 0,125 | 0,598 2 | 0,039 04 |
| 0,126 | 0,598 1 | 0,039 82 |
| 0,127 | 0,598 0 | 0,040 60 |
| 0,128 | 0,597 9 | 0,041 40 |
| 0,129 | 0,597 8 | 0,042 20 |
| 0,130 | 0,597 6 | 0,043 02 |
| 0,131 | 0,597 5 | 0,043 84 |
| 0,132 | 0,597 3 | 0,044 67 |
| 0,133 | 0,597 2 | 0,045 51 |
| 0,134 | 0,597 1 | 0,046 36 |
| 0,135 | 0,597 0 | 0,047 22 |
| 0,136 | 0,596 8 | 0,048 09 |
| 0,137 | 0,596 7 | 0,048 97 |
| 0,138 | 0,596 6 | 0,049 86 |
| 0,139 | 0,596 5 | 0,050 75 |
| 0,140 | 0,596 4 | 0,051 66 |
| 0,141 | 0,596 2 | 0,052 58 |
| 0,142 | 0,596 1 | 0,053 51 |
| 0,143 | 0,596 0 | 0,054 44 |
| 0,144 | 0,596 0 | 0,055 39 |
| 0,145 | 0,595 9 | 0,056 35 |

| Head<br>$h$<br>m | Coefficient<br>$C_d$ | Discharge<br>$Q$<br>$m^3/s \times 10^{-1}$ |
|---|---|---|
| 0,146 | 0,595 8 | 0,057 32 |
| 0,147 | 0,595 7 | 0,058 30 |
| 0,148 | 0,595 6 | 0,059 29 |
| 0,149 | 0,595 7 | 0,060 29 |
| 0,150 | 0,595 5 | 0,061 30 |
| 0,151 | 0,595 4 | 0,062 31 |
| 0,152 | 0,595 2 | 0,063 34 |
| 0,153 | 0,595 2 | 0,064 37 |
| 0,154 | 0,595 1 | 0,065 42 |
| 0,155 | 0,595 0 | 0,066 48 |
| 0,156 | 0,594 9 | 0,067 55 |
| 0,157 | 0,594 8 | 0,068 63 |
| 0,158 | 0,594 8 | 0,069 71 |
| 0,159 | 0,594 7 | 0,070 81 |
| 0,160 | 0,594 6 | 0,071 92 |
| 0,161 | 0,594 5 | 0,073 04 |
| 0,162 | 0,594 4 | 0,074 17 |
| 0,163 | 0,594 4 | 0,075 31 |
| 0,164 | 0,594 3 | 0,076 46 |
| 0,165 | 0,594 2 | 0,077 62 |
| 0,166 | 0,594 1 | 0,078 79 |
| 0,167 | 0,594 1 | 0,081 17 |
| 0,168 | 0,594 0 | 0,075 31 |
| 0,169 | 0,593 9 | 0,082 37 |
| 0,170 | 0,593 8 | 0,083 58 |
| 0,171 | 0,593 7 | 0,084 81 |
| 0,172 | 0,593 7 | 0,086 04 |
| 0,173 | 0,593 6 | 0,087 28 |
| 0,174 | 0,593 5 | 0,088 54 |
| 0,175 | 0,593 4 | 0,089 80 |
| 0,176 | 0,593 3 | 0,091 08 |
| 0,177 | 0,593 3 | 0,092 37 |

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**Table E.2** (*continued*)

| Head<br>$h$<br>m | Coefficient<br>$C_d$ | Discharge<br>$Q$<br>$m^3/s \times 10^{-1}$ |
|---|---|---|
| 0,178 | 0,593 2 | 0,093 67 |
| 0,179 | 0,593 1 | 0,094 97 |
| 0,180 | 0,593 0 | 0,096 29 |
| 0,181 | 0,592 9 | 0,097 62 |
| 0,182 | 0,592 9 | 0,098 96 |
| 0,183 | 0,592 8 | 0,100 32 |
| 0,184 | 0,592 7 | 0,101 68 |
| 0,185 | 0,592 6 | 0,103 05 |
| 0,186 | 0,592 6 | 0,104 44 |
| 0,187 | 0,592 5 | 0,105 84 |
| 0,188 | 0,592 5 | 0,107 26 |
| 0,189 | 0,592 4 | 0,108 67 |
| 0,190 | 0,592 3 | 0,110 10 |
| 0,191 | 0,592 3 | 0,111 55 |
| 0,192 | 0,592 2 | 0,113 00 |
| 0,193 | 0,592 2 | 0,114 47 |
| 0,194 | 0,592 1 | 0,115 95 |
| 0,195 | 0,592 0 | 0,117 43 |
| 0,196 | 0,592 0 | 0,118 93 |
| 0,197 | 0,591 9 | 0,120 44 |
| 0,198 | 0,591 9 | 0,121 97 |
| 0,199 | 0,591 9 | 0,123 51 |
| 0,200 | 0,591 8 | 0,125 06 |
| 0,201 | 0,591 8 | 0,126 62 |
| 0,202 | 0,591 7 | 0,128 19 |
| 0,203 | 0,591 7 | 0,129 77 |
| 0,204 | 0,591 6 | 0,131 36 |
| 0,205 | 0,591 6 | 0,132 96 |
| 0,206 | 0,591 5 | 0,134 57 |
| 0,207 | 0,591 5 | 0,136 20 |
| 0,208 | 0,591 4 | 0,137 84 |

| Head<br>$h$<br>m | Coefficient<br>$C_d$ | Discharge<br>$Q$<br>$m^3/s \times 10^{-1}$ |
|---|---|---|
| 0,209 | 0,591 3 | 0,139 49 |
| 0,210 | 0,591 3 | 0,141 15 |
| 0,211 | 0,591 2 | 0,142 82 |
| 0,212 | 0,591 2 | 0,144 50 |
| 0,213 | 0,591 1 | 0,146 20 |
| 0,214 | 0,591 1 | 0,147 92 |
| 0,215 | 0,591 0 | 0,149 64 |
| 0,216 | 0,591 0 | 0,151 38 |
| 0,217 | 0,591 0 | 0,153 13 |
| 0,218 | 0,590 9 | 0,154 89 |
| 0,219 | 0,590 9 | 0,156 66 |
| 0,220 | 0,590 8 | 0,158 44 |
| 0,221 | 0,590 8 | 0,160 24 |
| 0,222 | 0,590 8 | 0,162 04 |
| 0,223 | 0,590 7 | 0,163 86 |
| 0,224 | 0,590 7 | 0,165 70 |
| 0,225 | 0,590 6 | 0,167 54 |
| 0,226 | 0,590 6 | 0,169 40 |
| 0,227 | 0,590 6 | 0,171 27 |
| 0,228 | 0,590 5 | 0,173 15 |
| 0,229 | 0,590 5 | 0,175 04 |
| 0,230 | 0,590 4 | 0,176 95 |
| 0,231 | 0,590 4 | 0,178 86 |
| 0,232 | 0,590 4 | 0,180 79 |
| 0,233 | 0,590 3 | 0,182 74 |
| 0,234 | 0,590 3 | 0,184 69 |
| 0,235 | 0,590 2 | 0,186 66 |
| 0,236 | 0,590 2 | 0,188 64 |
| 0,237 | 0,590 2 | 0,190 63 |
| 0,238 | 0,590 1 | 0,192 63 |
| 0,239 | 0,590 1 | 0,194 65 |


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**Table E.2** (*continued*)

| Head $h$ m | Coefficient $C_d$ | Discharge $Q$ $m^3/s \times 10^{-1}$ | Head $h$ m | Coefficient $C_d$ | Discharge $Q$ $m^3/s \times 10^{-1}$ |
|---|---|---|---|---|---|
| 0,240 | 0,590 1 | 0,196 68 | 0,271 | 0,589 1 | 0,266 06 |
| 0,241 | 0,590 0 | 0,198 72 | 0,272 | 0,589 1 | 0,268 51 |
| 0,242 | 0,590 0 | 0,200 79 | 0,273 | 0,589 1 | 0,270 98 |
| 0,243 | 0,590 0 | 0,202 87 | 0,274 | 0,589 1 | 0,273 47 |
| 0,244 | 0,589 9 | 0,204 96 | 0,275 | 0,589 1 | 0,275 96 |
| 0,245 | 0,589 9 | 0,207 05 | 0,276 | 0,589 0 | 0,278 45 |
| 0,246 | 0,589 8 | 0,209 16 | 0,277 | 0,589 0 | 0,280 97 |
| 0,247 | 0,589 8 | 0,211 27 | 0,278 | 0,589 0 | 0,283 51 |
| 0,248 | 0,589 8 | 0,213 40 | 0,279 | 0,589 0 | 0,286 07 |
| 0,249 | 0,589 8 | 0,215 55 | | | |
| | | | 0,280 | 0,589 0 | 0,288 63 |
| 0,250 | 0,589 8 | 0,217 72 | 0,281 | 0,588 9 | 0,291 19 |
| 0,251 | 0,589 8 | 0,219 90 | 0,282 | 0,588 9 | 0,293 77 |
| 0,252 | 0,589 8 | 0,222 09 | 0,283 | 0,588 9 | 0,296 38 |
| 0,253 | 0,589 7 | 0,224 29 | 0,284 | 0,588 9 | 0,299 01 |
| 0,254 | 0,589 7 | 0,226 49 | 0,285 | 0,588 9 | 0,301 63 |
| 0,255 | 0,589 7 | 0,228 73 | 0,286 | 0,588 8 | 0,304 27 |
| 0,256 | 0,589 7 | 0,230 98 | 0,287 | 0,588 8 | 0,306 91 |
| 0,257 | 0,589 7 | 0,233 23 | 0,288 | 0,588 8 | 0,309 59 |
| 0,258 | 0,589 6 | 0,235 49 | 0,289 | 0,588 8 | 0,312 29 |
| 0,259 | 0,589 6 | 0,237 77 | | | |
| | | | 0,290 | 0,588 8 | 0,314 99 |
| 0,260 | 0,589 6 | 0,240 05 | 0,291 | 0,588 7 | 0,317 69 |
| 0,261 | 0,589 5 | 0,242 35 | 0,292 | 0,588 7 | 0,320 40 |
| 0,262 | 0,589 5 | 0,244 66 | 0,293 | 0,588 7 | 0,323 15 |
| 0,263 | 0,589 4 | 0,246 99 | 0,294 | 0,588 7 | 0,325 91 |
| 0,264 | 0,589 4 | 0,249 33 | 0,295 | 0,588 7 | 0,328 69 |
| 0,265 | 0,589 4 | 0,251 68 | 0,296 | 0,588 6 | 0,331 46 |
| 0,266 | 0,589 3 | 0,254 04 | 0,297 | 0,588 6 | 0,334 24 |
| 0,267 | 0,589 3 | 0,256 42 | 0,298 | 0,588 6 | 0,337 04 |
| 0,268 | 0,589 2 | 0,258 81 | 0,299 | 0,588 5 | 0,339 85 |
| 0,269 | 0,589 2 | 0,261 21 | | | |
| | | | 0,300 | 0,588 5 | 0,342 68 |
| 0,270 | 0,589 2 | 0,263 63 | 0,301 | 0,588 4 | 0,345 52 |

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**Table E.2** (*continued*)

| Head<br>$h$<br>m | Coefficient<br>$C_d$ | Discharge<br>$Q$<br>$m^3/s \times 10^{-1}$ |
|---|---|---|
| 0,302 | 0,588 4 | 0,348 37 |
| 0,303 | 0,588 4 | 0,351 24 |
| 0,304 | 0,588 3 | 0,354 12 |
| 0,305 | 0,588 3 | 0,357 02 |
| 0,306 | 0,588 3 | 0,359 95 |
| 0,307 | 0,588 3 | 0,362 90 |
| 0,308 | 0,588 3 | 0,365 85 |
| 0,309 | 0,588 2 | 0,368 80 |
| 0,310 | 0,588 2 | 0,371 77 |
| 0,311 | 0,588 2 | 0,347 77 |
| 0,312 | 0,588 2 | 0,377 79 |
| 0,313 | 0,588 2 | 0,380 81 |
| 0,314 | 0,588 1 | 0,383 84 |
| 0,315 | 0,588 1 | 0,386 87 |
| 0,316 | 0,588 1 | 0,389 95 |
| 0,317 | 0,588 1 | 0,393 04 |
| 0,318 | 0,588 1 | 0,396 15 |
| 0,319 | 0,588 1 | 0,399 27 |
| 0,320 | 0,588 1 | 0,402 41 |
| 0,321 | 0,588 1 | 0,405 53 |
| 0,322 | 0,588 0 | 0,408 67 |
| 0,323 | 0,588 0 | 0,411 84 |
| 0,324 | 0,588 0 | 0,415 03 |
| 0,325 | 0,588 0 | 0,418 24 |
| 0,326 | 0,588 0 | 0,421 47 |
| 0,327 | 0,588 0 | 0,424 71 |
| 0,328 | 0,588 0 | 0,427 96 |
| 0,329 | 0,588 0 | 0,431 23 |
| 0,330 | 0,588 0 | 0,434 51 |
| 0,331 | 0,588 0 | 0,437 79 |
| 0,332 | 0,587 9 | 0,441 07 |

| Head<br>$h$<br>m | Coefficient<br>$C_d$ | Discharge<br>$Q$<br>$m^3/s \times 10^{-1}$ |
|---|---|---|
| 0,333 | 0,587 9 | 0,444 38 |
| 0,334 | 0,587 9 | 0,447 73 |
| 0,335 | 0,587 9 | 0,451 08 |
| 0,336 | 0,587 9 | 0,454 46 |
| 0,337 | 0,587 9 | 0,457 85 |
| 0,338 | 0,587 9 | 0,461 25 |
| 0,339 | 0,587 9 | 0,464 67 |
| 0,340 | 0,587 9 | 0,468 10 |
| 0,341 | 0,587 9 | 0,471 53 |
| 0,342 | 0,587 8 | 0,474 97 |
| 0,343 | 0,587 8 | 0,478 42 |
| 0,344 | 0,587 8 | 0,481 91 |
| 0,345 | 0,587 8 | 0,485 42 |
| 0,346 | 0,587 8 | 0,488 95 |
| 0,347 | 0,587 8 | 0,492 49 |
| 0,348 | 0,587 8 | 0,496 04 |
| 0,349 | 0,587 8 | 0,499 58 |
| 0,350 | 0,587 7 | 0,503 13 |
| 0,351 | 0,587 7 | 0,506 72 |
| 0,352 | 0,587 7 | 0,510 33 |
| 0,353 | 0,587 7 | 0,513 97 |
| 0,354 | 0,587 7 | 0,517 58 |
| 0,355 | 0,587 6 | 0,521 21 |
| 0,356 | 0,587 6 | 0,524 87 |
| 0,357 | 0,587 6 | 0,528 56 |
| 0,358 | 0,587 6 | 0,532 27 |
| 0,359 | 0,587 6 | 0,535 96 |
| 0,360 | 0,587 5 | 0,539 67 |
| 0,361 | 0,587 5 | 0,543 40 |
| 0,362 | 0,587 5 | 0,547 17 |
| 0,363 | 0,587 5 | 0,550 96 |


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**Table E.2** (*continued*)

| Head<br>$h$<br>m | Coefficient<br>$C_d$ | Discharge<br>$Q$<br>$m^3/s \times 10^{-1}$ |
|---|---|---|
| 0,364 | 0,587 5 | 0,554 73 |
| 0,365 | 0,587 4 | 0,558 51 |
| 0,366 | 0,587 4 | 0,562 31 |
| 0,367 | 0,587 4 | 0,566 16 |
| 0,368 | 0,587 4 | 0,570 03 |
| 0,369 | 0,587 4 | 0,573 91 |
| 0,370 | 0,587 4 | 0,577 80 |
| 0,371 | 0,587 4 | 0,581 71 |
| 0,372 | 0,587 4 | 0,585 60 |
| 0,373 | 0,587 3 | 0,589 50 |

| Head<br>$h$<br>m | Coefficient<br>$C_d$ | Discharge<br>$Q$<br>$m^3/s \times 10^{-1}$ |
|---|---|---|
| 0,374 | 0,587 3 | 0,593 45 |
| 0,375 | 0,587 3 | 0,597 42 |
| 0,376 | 0,587 3 | 0,601 41 |
| 0,377 | 0,587 3 | 0,605 42 |
| 0,378 | 0,587 3 | 0,609 44 |
| 0,379 | 0,587 3 | 0,613 46 |
| 0,380 | 0,587 2 | 0,617 47 |
| 0,381 | 0,587 2 | 0,621 50 |

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**Table E.3 — Discharge of water over a V-notch with** $\tan \frac{\alpha}{2} = 1/4$ ($\alpha = 0{,}489\ 9$ radian or 28° 4′)

$$Q = 0{,}590\ 625\ C_d h^{5/2}$$

$$(g = 9{,}806\ 6\ \text{m/s}^2)$$

| Head $h$ m | Coefficient $C_d$ | Discharge $Q$ $m^3/s \times 10^{-1}$ | Head $h$ m | Coefficient $C_d$ | Discharge $Q$ $m^3/s \times 10^{-1}$ |
|---|---|---|---|---|---|
| 0,060 | 0,641 7 | 0,003 34 | 0,090 | 0,625 6 | 0,008 98 |
| 0,061 | 0,641 0 | 0,003 48 | 0,091 | 0,625 2 | 0,009 22 |
| 0,062 | 0,640 3 | 0,003 62 | 0,092 | 0,624 8 | 0,009 47 |
| 0,063 | 0,639 6 | 0,003 76 | 0,093 | 0,624 4 | 0,009 73 |
| 0,064 | 0,639 0 | 0,003 91 | 0,094 | 0,624 0 | 0,009 98 |
| 0,065 | 0,638 3 | 0,004 06 | 0,095 | 0,623 6 | 0,010 25 |
| 0,066 | 0,637 6 | 0,004 21 | 0,096 | 0,623 3 | 0,010 51 |
| 0,067 | 0,637 0 | 0,004 37 | 0,097 | 0,622 9 | 0,010 78 |
| 0,068 | 0,636 4 | 0,004 53 | 0,098 | 0,622 6 | 0,011 06 |
| 0,069 | 0,635 8 | 0,004 70 | 0,099 | 0,622 2 | 0,011 33 |
| 0,070 | 0,635 2 | 0,004 86 | 0,100 | 0,621 9 | 0,011 61 |
| 0,071 | 0,634 6 | 0,005 03 | 0,101 | 0,621 5 | 0,011 90 |
| 0,072 | 0,634 0 | 0,005 21 | 0,102 | 0,621 2 | 0,012 19 |
| 0,073 | 0,633 5 | 0,005 39 | 0,103 | 0,620 9 | 0,012 49 |
| 0,074 | 0,632 9 | 0,005 57 | 0,104 | 0,620 5 | 0,012 78 |
| 0,075 | 0,632 4 | 0,005 75 | 0,105 | 0,620 2 | 0,013 09 |
| 0,076 | 0,631 8 | 0,005 94 | 0,106 | 0,619 9 | 0,013 39 |
| 0,077 | 0,631 3 | 0,006 13 | 0,107 | 0,619 6 | 0,013 71 |
| 0,078 | 0,630 8 | 0,006 33 | 0,108 | 0,619 3 | 0,014 02 |
| 0,079 | 0,630 3 | 0,006 53 | 0,109 | 0,619 0 | 0,014 34 |
| 0,080 | 0,629 8 | 0,006 73 | 0,110 | 0,618 7 | 0,014 66 |
| 0,081 | 0,629 3 | 0,006 94 | 0,111 | 0,618 4 | 0,014 99 |
| 0,082 | 0,628 9 | 0,007 15 | 0,112 | 0,618 1 | 0,015 33 |
| 0,083 | 0,628 5 | 0,007 37 | 0,113 | 0,617 9 | 0,015 66 |
| 0,084 | 0,628 0 | 0,007 59 | 0,114 | 0,617 6 | 0,016 01 |
| 0,085 | 0,627 6 | 0,007 81 | 0,115 | 0,617 3 | 0,016 35 |
| 0,086 | 0,627 2 | 0,008 03 | 0,116 | 0,617 1 | 0,016 70 |
| 0,087 | 0,626 7 | 0,008 26 | 0,117 | 0,616 9 | 0,017 06 |
| 0,088 | 0,626 4 | 0,008 50 | 0,118 | 0,616 6 | 0,017 42 |
| 0,089 | 0,626 0 | 0,008 74 | 0,119 | 0,616 4 | 0,017 78 |


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**Table E.3** (*continued*)

| Head $h$ m | Coefficient $C_d$ | Discharge $Q$ $m^3/s \times 10^{-1}$ | Head $h$ m | Coefficient $C_d$ | Discharge $Q$ $m^3/s \times 10^{-1}$ |
|---|---|---|---|---|---|
| 0,120 | 0,616 2 | 0,018 15 | 0,154 | 0,609 5 | 0,033 50 |
| 0,121 | 0,616 0 | 0,018 53 | 0,155 | 0,609 3 | 0,034 04 |
| 0,122 | 0,615 8 | 0,018 91 | 0,156 | 0,609 1 | 0,034 58 |
| 0,123 | 0,615 5 | 0,019 29 | 0,157 | 0,609 0 | 0,035 13 |
| 0,124 | 0,615 3 | 0,019 68 | 0,158 | 0,608 8 | 0,035 68 |
| 0,125 | 0,615 1 | 0,020 07 | 0,159 | 0,608 7 | 0,036 24 |
| 0,126 | 0,614 8 | 0,020 46 | | | |
| 0,127 | 0,614 6 | 0,020 86 | 0,160 | 0,608 5 | 0,036 80 |
| 0,128 | 0,614 4 | 0,021 27 | 0,161 | 0,608 3 | 0,037 37 |
| 0,129 | 0,614 1 | 0,021 68 | 0,162 | 0,608 2 | 0,037 94 |
| | | | 0,163 | 0,608 0 | 0,038 52 |
| 0,130 | 0,613 9 | 0,022 09 | 0,164 | 0,607 9 | 0,039 11 |
| 0,131 | 0,613 7 | 0,022 51 | 0,165 | 0,607 7 | 0,039 69 |
| 0,132 | 0,613 5 | 0,022 94 | 0,166 | 0,607 6 | 0,040 29 |
| 0,133 | 0,613 3 | 0,023 37 | 0,167 | 0,607 4 | 0,040 89 |
| 0,134 | 0,613 1 | 0,023 80 | 0,168 | 0,607 3 | 0,041 49 |
| 0,135 | 0,612 9 | 0,024 24 | 0,169 | 0,607 1 | 0,042 10 |
| 0,136 | 0,612 7 | 0,024 68 | | | |
| 0,137 | 0,612 5 | 0,025 13 | 0,170 | 0,607 0 | 0,042 72 |
| 0,138 | 0,612 3 | 0,025 59 | 0,171 | 0,606 9 | 0,043 34 |
| 0,139 | 0,612 1 | 0,026 04 | 0,172 | 0,606 8 | 0,043 97 |
| | | | 0,173 | 0,606 7 | 0,044 60 |
| 0,140 | 0,611 9 | 0,026 51 | 0,174 | 0,606 5 | 0,045 24 |
| 0,141 | 0,611 7 | 0,026 97 | 0,175 | 0,606 3 | 0,045 88 |
| 0,142 | 0,611 5 | 0,027 44 | 0,176 | 0,606 2 | 0,046 53 |
| 0,143 | 0,611 3 | 0,027 92 | 0,177 | 0,606 1 | 0,047 18 |
| 0,144 | 0,611 2 | 0,028 40 | 0,178 | 0,606 0 | 0,047 84 |
| 0,145 | 0,611 0 | 0,028 89 | 0,179 | 0,605 9 | 0,048 51 |
| 0,146 | 0,610 8 | 0,029 38 | | | |
| 0,147 | 0,610 6 | 0,029 88 | 0,180 | 0,605 7 | 0,049 18 |
| 0,148 | 0,610 5 | 0,030 38 | 0,181 | 0,605 6 | 0,049 86 |
| 0,149 | 0,610 3 | 0,030 89 | 0,182 | 0,605 5 | 0,050 54 |
| | | | 0,183 | 0,605 4 | 0,051 22 |
| 0,150 | 0,610 2 | 0,031 40 | 0,184 | 0,605 3 | 0,051 92 |
| 0,151 | 0,610 0 | 0,031 92 | 0,185 | 0,605 1 | 0,052 61 |
| 0,152 | 0,609 9 | 0,032 45 | 0,186 | 0,605 1 | 0,053 32 |
| 0,153 | 0,609 7 | 0,032 97 | 0,187 | 0,605 0 | 0,054 03 |

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**Table E.3** (*continued*)

| Head<br>$h$<br>m | Coefficient<br>$C_d$ | Discharge<br>$Q$<br>$m^3/s \times 10^{-1}$ | Head<br>$h$<br>m | Coefficient<br>$C_d$ | Discharge<br>$Q$<br>$m^3/s \times 10^{-1}$ |
|---|---|---|---|---|---|
| 0,188 | 0,604 9 | 0,054 75 | 0,221 | 0,602 0 | 0,081 64 |
| 0,189 | 0,604 8 | 0,055 47 | 0,222 | 0,601 9 | 0,082 55 |
| | | | 0,223 | 0,601 8 | 0,083 47 |
| 0,190 | 0,604 7 | 0,056 20 | 0,224 | 0,601 8 | 0,084 41 |
| 0,191 | 0,604 5 | 0,056 93 | 0,225 | 0,601 7 | 0,085 35 |
| 0,192 | 0,604 4 | 0,057 66 | 0,226 | 0,601 7 | 0,086 29 |
| 0,193 | 0,604 3 | 0,058 41 | 0,227 | 0,601 6 | 0,087 24 |
| 0,194 | 0,604 2 | 0,059 16 | 0,228 | 0,601 5 | 0,088 19 |
| 0,195 | 0,604 1 | 0,059 92 | 0,229 | 0,601 5 | 0,089 15 |
| 0,196 | 0,604 1 | 0,060 68 | | | |
| 0,197 | 0,604 0 | 0,061 45 | 0,230 | 0,601 4 | 0,090 11 |
| 0,198 | 0,603 9 | 0,062 22 | 0,231 | 0,601 3 | 0,091 08 |
| 0,199 | 0,603 8 | 0,063 00 | 0,232 | 0,601 3 | 0,092 07 |
| | | | 0,233 | 0,601 2 | 0,093 06 |
| 0,200 | 0,603 8 | 0,063 79 | 0,234 | 0,601 2 | 0,094 05 |
| 0,201 | 0,603 7 | 0,064 58 | 0,235 | 0,601 1 | 0,095 04 |
| 0,202 | 0,603 5 | 0,065 37 | 0,236 | 0,601 0 | 0,096 05 |
| 0,203 | 0,603 4 | 0,066 17 | 0,237 | 0,601 0 | 0,097 06 |
| 0,204 | 0,603 3 | 0,066 98 | 0,238 | 0,600 9 | 0,098 08 |
| 0,205 | 0,603 3 | 0,067 80 | 0,239 | 0,600 9 | 0,099 10 |
| 0,206 | 0,603 2 | 0,068 62 | | | |
| 0,207 | 0,603 1 | 0,069 44 | 0,240 | 0,600 8 | 0,100 13 |
| 0,208 | 0,603 0 | 0,070 28 | 0,241 | 0,600 7 | 0,101 16 |
| 0,209 | 0,602 9 | 0,071 11 | 0,242 | 0,600 6 | 0,102 20 |
| | | | 0,243 | 0,600 6 | 0,103 25 |
| 0,210 | 0,602 9 | 0,071 96 | 0,244 | 0,600 5 | 0,104 30 |
| 0,211 | 0,602 8 | 0,072 81 | 0,245 | 0,600 4 | 0,105 36 |
| 0,212 | 0,602 7 | 0,073 66 | 0,246 | 0,600 3 | 0,106 42 |
| 0,213 | 0,602 6 | 0,074 53 | 0,247 | 0,600 3 | 0,107 50 |
| 0,214 | 0,602 5 | 0,075 39 | 0,248 | 0,600 2 | 0,108 58 |
| 0,215 | 0,602 5 | 0,076 27 | 0,249 | 0,600 2 | 0,109 67 |
| 0,216 | 0,602 4 | 0,077 15 | | | |
| 0,217 | 0,602 3 | 0,078 03 | 0,250 | 0,600 2 | 0,110 77 |
| 0,218 | 0,602 2 | 0,078 93 | 0,251 | 0,600 1 | 0,111 87 |
| 0,219 | 0,602 2 | 0,079 82 | 0,252 | 0,600 1 | 0,112 99 |
| | | | 0,253 | 0,600 0 | 0,114 10 |
| 0,220 | 0,602 1 | 0,080 73 | 0,254 | 0,600 0 | 0,115 23 |


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**Table E.3** (*continued*)

| Head $h$ m | Coefficient $C_d$ | Discharge $Q$ $m^3/s \times 10^{-1}$ |
|---|---|---|
| 0,255 | 0,600 0 | 0,116 35 |
| 0,256 | 0,599 9 | 0,117 49 |
| 0,257 | 0,599 9 | 0,118 63 |
| 0,258 | 0,599 8 | 0,119 78 |
| 0,259 | 0,599 8 | 0,120 94 |
| 0,260 | 0,599 7 | 0,122 10 |
| 0,261 | 0,599 6 | 0,123 26 |
| 0,262 | 0,599 6 | 0,124 43 |
| 0,263 | 0,599 5 | 0,125 61 |
| 0,264 | 0,599 5 | 0,126 80 |
| 0,265 | 0,599 5 | 0,127 99 |
| 0,266 | 0,599 4 | 0,129 20 |
| 0,267 | 0,599 4 | 0,130 41 |
| 0,268 | 0,599 3 | 0,131 62 |
| 0,269 | 0,599 3 | 0,132 84 |
| 0,270 | 0,599 2 | 0,134 07 |
| 0,271 | 0,599 2 | 0,135 29 |
| 0,272 | 0,599 1 | 0,136 53 |
| 0,273 | 0,599 1 | 0,137 78 |
| 0,274 | 0,599 0 | 0,139 03 |
| 0,275 | 0,599 0 | 0,140 30 |
| 0,276 | 0,598 9 | 0,141 57 |
| 0,277 | 0,598 9 | 0,142 84 |
| 0,278 | 0,598 9 | 0,144 13 |
| 0,279 | 0,598 8 | 0,145 42 |
| 0,280 | 0,598 8 | 0,146 71 |
| 0,281 | 0,598 7 | 0,148 02 |
| 0,282 | 0,598 7 | 0,149 33 |
| 0,283 | 0,598 7 | 0,150 65 |
| 0,284 | 0,598 6 | 0,151 97 |
| 0,285 | 0,598 6 | 0,153 30 |
| 0,286 | 0,598 5 | 0,154 64 |
| 0,287 | 0,598 5 | 0,155 98 |
| 0,288 | 0,598 5 | 0,157 34 |

| Head $h$ m | Coefficient $C_d$ | Discharge $Q$ $m^3/s \times 10^{-1}$ |
|---|---|---|
| 0,289 | 0,598 4 | 0,158 70 |
| 0,290 | 0,598 4 | 0,160 06 |
| 0,291 | 0,598 3 | 0,161 43 |
| 0,292 | 0,598 3 | 0,162 81 |
| 0,293 | 0,598 3 | 0,164 20 |
| 0,294 | 0,598 2 | 0,165 59 |
| 0,295 | 0,598 2 | 0,166 99 |
| 0,296 | 0,598 1 | 0,168 40 |
| 0,297 | 0,598 1 | 0,169 82 |
| 0,298 | 0,598 1 | 0,171 24 |
| 0,299 | 0,598 0 | 0,172 67 |
| 0,300 | 0,598 0 | 0,174 10 |
| 0,301 | 0,597 9 | 0,175 55 |
| 0,302 | 0,597 9 | 0,177 00 |
| 0,303 | 0,597 9 | 0,178 45 |
| 0,304 | 0,597 8 | 0,179 92 |
| 0,305 | 0,597 8 | 0,181 39 |
| 0,306 | 0,597 8 | 0,182 87 |
| 0,307 | 0,597 7 | 0,184 35 |
| 0,308 | 0,597 7 | 0,185 85 |
| 0,309 | 0,597 6 | 0,187 35 |
| 0,310 | 0,597 6 | 0,188 85 |
| 0,311 | 0,597 6 | 0,190 37 |
| 0,312 | 0,597 5 | 0,191 89 |
| 0,313 | 0,597 5 | 0,193 42 |
| 0,314 | 0,597 4 | 0,194 95 |
| 0,315 | 0,597 4 | 0,196 50 |
| 0,316 | 0,597 4 | 0,198 05 |
| 0,317 | 0,597 3 | 0,199 60 |
| 0,318 | 0,597 3 | 0,201 17 |
| 0,319 | 0,597 2 | 0,202 74 |
| 0,320 | 0,597 2 | 0,204 32 |
| 0,321 | 0,597 2 | 0,205 90 |

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**Table E.3** (*continued*)

| Head<br>$h$<br>m | Coefficient<br>$C_d$ | Discharge<br>$Q$<br>$m^3/s \times 10^{-1}$ |
|---|---|---|
| 0,322 | 0,597 1 | 0,207 50 |
| 0,323 | 0,597 1 | 0,209 10 |
| 0,324 | 0,597 0 | 0,210 71 |
| 0,325 | 0,597 0 | 0,212 32 |
| 0,326 | 0,597 0 | 0,213 95 |
| 0,327 | 0,596 9 | 0,215 58 |
| 0,328 | 0,596 9 | 0,217 21 |
| 0,329 | 0,596 9 | 0,218 86 |
| 0,330 | 0,596 8 | 0,220 51 |
| 0,331 | 0,596 8 | 0,222 17 |
| 0,332 | 0,596 7 | 0,223 84 |
| 0,333 | 0,596 7 | 0,225 51 |
| 0,334 | 0,596 7 | 0,227 19 |
| 0,335 | 0,596 6 | 0,228 88 |
| 0,336 | 0,596 6 | 0,230 58 |
| 0,337 | 0,596 5 | 0,232 28 |
| 0,338 | 0,596 5 | 0,234 00 |
| 0,339 | 0,596 5 | 0,235 72 |
| 0,340 | 0,596 4 | 0,237 44 |
| 0,341 | 0,596 4 | 0,239 18 |
| 0,342 | 0,596 3 | 0,240 92 |
| 0,343 | 0,596 3 | 0,242 57 |
| 0,344 | 0,596 3 | 0,244 42 |
| 0,345 | 0,596 2 | 0,246 19 |
| 0,346 | 0,596 2 | 0,247 96 |
| 0,347 | 0,596 1 | 0,249 74 |
| 0,348 | 0,596 1 | 0,251 52 |
| 0,349 | 0,596 1 | 0,253 32 |
| 0,350 | 0,596 0 | 0,255 12 |
| 0,351 | 0,596 0 | 0,256 93 |
| 0,352 | 0,595 9 | 0,258 75 |
| 0,353 | 0,595 9 | 0,260 57 |
| 0,354 | 0,595 9 | 0,262 40 |
| 0,355 | 0,595 8 | 0,264 24 |
| 0,356 | 0,595 8 | 0,266 09 |
| 0,357 | 0,595 7 | 0,267 94 |
| 0,358 | 0,595 7 | 0,269 81 |
| 0,359 | 0,595 7 | 0,271 68 |
| 0,360 | 0,596 0 | 0,255 12 |
| 0,361 | 0,596 0 | 0,256 93 |
| 0,362 | 0,595 9 | 0,258 75 |
| 0,363 | 0,595 9 | 0,260 57 |
| 0,364 | 0,595 9 | 0,262 40 |
| 0,365 | 0,595 8 | 0,264 24 |
| 0,366 | 0,595 8 | 0,266 09 |
| 0,367 | 0,595 7 | 0,267 94 |
| 0,368 | 0,595 7 | 0,269 81 |
| 0,369 | 0,595 7 | 0,271 68 |
| 0,370 | 0,595 2 | 0,292 75 |
| 0,371 | 0,595 2 | 0,294 72 |
| 0,372 | 0,595 2 | 0,296 69 |
| 0,373 | 0,595 1 | 0,298 67 |
| 0,374 | 0,595 1 | 0,300 65 |
| 0,375 | 0,595 0 | 0,302 64 |
| 0,376 | 0,595 0 | 0,304 65 |
| 0,377 | 0,595 0 | 0,306 66 |
| 0,378 | 0,594 9 | 0,308 67 |
| 0,379 | 0,594 9 | 0,310 70 |
| 0,380 | 0,594 8 | 0,312 73 |
| 0,381 | 0,594 8 | 0,314 77 |


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